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Building a reliable snare cable for capturing grizzly and American black bears

John P. Flaa[1,4], Steve B. Michel[2], and Chris Borstad[3]

[1]*Mount Revelstoke and Glacier National Parks, Box 350, Revelstoke, BC V0E 2S0, Canada*
[2]*Banff National Park, Box 900, Banff, AB T1L 1K2, Canada*
[3]*University of British Columbia, Department of Civil Engineering, 1984 West Mall, Vancouver, BC V6T 1Z2, Canada*

Abstract: Wildlife researchers and managers have been using Aldrich foot snares to capture American black bears (*Ursus americanus*) and grizzly bears (*U. arctos*) for decades. Recently, failures have been reported in snare cable assemblies, resulting in escapes of both black and grizzly bears. We tested different configurations of snare cable and hardware using a hydraulic pull machine. Snare foot loops constructed with compression sleeves or Crosby® clips torqued to 20.3 newton-meters (N-m) consistently exceeded minimum strength requirements for use on large bears (>16.8 kilonewton [kN]). In our tests, anchor sections of snares using compression sleeves and 0.794 cm swivels never failed below 30 kN. It is important to use robust, manufacturer-rated hardware and precise methodology when building snare cables to achieve consistent holding strength. The use of substandard components and improper torquing of clamps can result in failure of the snare endangering both bears and capture personnel.

Key words: Aldrich foot snare, bears, cables, capturing bears, clamps, clips, safety, sleeves, swivels, torque

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Thousands of bears have been live-captured using variations of the Aldrich foot snare, and relatively few have escaped the system once captured (Johnson and Pelton 1980, Reagan et al. 2002, Lemieux and Czetwertynski 2006). However, in 2007, a male grizzly bear (*Ursus arctos*; 200 kg when captured in 2005) broke a foot loop while we approached it to remotely deliver an immobilization drug. Snares failed in 2 other recent instances, we know of, during the capture of American black (*Ursus americanus*) and grizzly bears (personal communications: B. McLellan, BC Forest Service, D'Arcy, British Columbia, Canada, 2007; E. Wenum, Montana Fish, Wildlife & Parks, Kalispell, Montana, USA, 2007). An Amur tiger (*Panthera tigris altaica*) snare-captured in the Russian Far East also escaped in 2008 (C. Miller, Wildlife Conservation Society, Vladivostok, Primorski Krai, Russia, personal communication, 2008). When a bear escapes a snare there is a high potential for serious injury or death both to the bear and to capture personnel.

Jonkel (1993) and Johnson and Pelton (1980) described traditional methods of building snares and their use for the live-capture of bears. There are several other unpublished and informal descriptions of the use and construction of snares; however, we found no research that quantified breaking strength of snares used to trap bears. Hence, our objective was to determine which snare components and configurations would provide the greatest holding strength and thus be the most reliable.

Methods

A hydraulic pull machine was used to estimate the strength of different snare configurations and components (Fig. 1). We used 2 types of pull tests. In the first we performed a single pull until the point of snare failure. In the second, we performed a series of repeated pulls to simulate repeated lunges by a bear in a snare. Tests were conducted at the Basecamp Innovations Ltd. facility near Invermere, British Columbia, Canada. We investigated hardware specifications and spoke to product representatives for Nicopress® (The National Telephone Supply Company, Cleveland Ohio, USA) and Crosby® clips (The Crosby Group, Inc., Tulsa, Oklahoma, USA) to discuss product recommendations and variances specific to our use.

Phillips et al. (1990) evaluated different types of breakaway snares used to capture coyotes (*Canis*

[4]John.Flaa@pc.gc.ca

T. Spraker

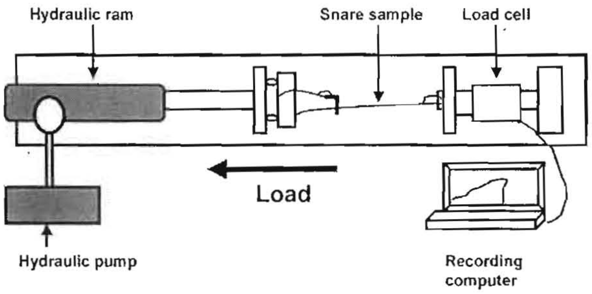

Fig. 1. Hydraulic pull machine (Basecamp Innovations Ltd.) used to test mountain rescue and climbing equipment, which we adapted to test cable strength for bear snares.

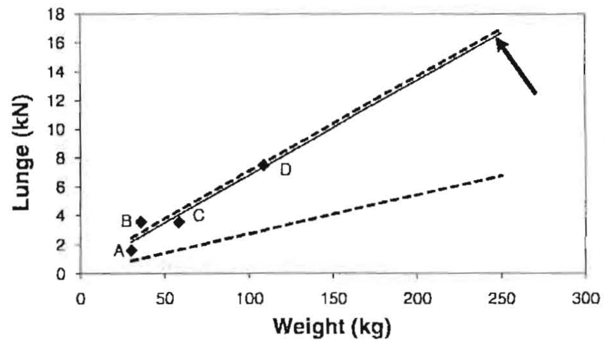

Fig. 2. The maximum force (kilonewtons, kN) of A = mule deer fawn (30 kg), B = lamb (36 kg), C = mule deer adult (59 kg) and D = cow calf (109 kg), lunging on a 1.5 m snare cable (Phillips et al. 1990). The solid line extends the trend of this maximum force; the arrow at 16.8 kN estimates of the force a 250-kg bear may exert on a snare cable. The dashed lines are 95% CI of the mean of lunge forces from Phillips et al. (1990).

latrans). They tested the tension (lunge force) that domestic lambs, mule deer (*Odocoileus hemionus*) fawns and adults, and domestic calves exerted on the snare assembly. Using body mass, we extrapolated their results to determine the potential force a bear may exert on a snare (Fig. 2). We used the maximum of the ranges reported by Phillips et al. (1990) to derive a benchmark force for bears (16.8 kilonewtons [kN]). Phillips et al. (1990) reported a wide range of behavior in snare-captured animals during their study. Our observations of captured black and grizzly bears are similar; therefore, the 16.8 kN benchmark is only a minimum target that snares had to exceed to be considered acceptable.

We tested several snare components and configurations. First, we tested the strength of a generic cable clamp found in most hardware stores and a Crosby® clip, which is robust and manufacturer-tested and rated. Second, we tested the integrity of a Crosby® clip when applied in either of 2 ways: with the clip saddle on the short end of a wire rope ('saddle on a dead horse') or with the clip saddle on the long end of a wire rope ('saddle on a live horse'). Although the manufacturer's recommended application is the live horse configuration, most capture personnel prefer the dead horse configuration to reduce injury to the legs of a captured bear from the clip bolts. We also tested the holding power of saddle clamps after being hand-tightened (holding the clamp in one hand and tightening the clamp nuts with a wrench in the other hand) or tightened with a torque wrench to a specified force. We examined whether welding the ends of the snare cable affected clamp performance. Finally, we strength-tested other snare components including compression sleeves, swivels, and the angle iron sliders used as locks on cable foot loops.

Pull test

Pull tests were conducted using a hydraulic pull machine with a 40 kN load cell, accurate to 0.5% at full-scale value (Fig. 1). A simulated bear leg was constructed using a 7.3 cm (outside diameter) steel pipe wrapped in 0.95 cm closed-cell foam with an outer layer of leather. All cable used in the testing was 7 x 19 galvanized aircraft 0.635 cm cable, used by most capture personnel in western North America where grizzly bears occur. We used 0.635 cm aluminum sleeves in tests where cable loops were swaged. Two types of saddle clamps were tested, Crosby® 0.635 cm clips (G-450), and generic 0.635 cm clamps. We used 0.794 cm swivels to make connections between the anchor and foot loop sections of the snare cable (Fig. 3).

We tested 7 configurations of cable and hardware for a total of 51 tests (Table 1). Test 1 consisted of a swaged loop (wire cable held in a loop with an aluminum oval compression sleeve) and a foot loop with a slider and a Crosby® clip on a dead horse loop torqued to 20.3 Nm (newton-meters; 15 foot pounds [ft-lb]). Test 2 consisted of a swaged loop and a Crosby® clip on a live horse loop torqued to 20.3 Nm. Test 3 had a swaged loop at the slider as well as the anchor end. Test 4 consisted of a swaged loop, slider, and a hand-tightened generic clamp. In test 5 the clamp was torqued to 20.3 Nm. Test 6 consisted of a swaged loop, slider, and a hand-tightened Crosby® clip.

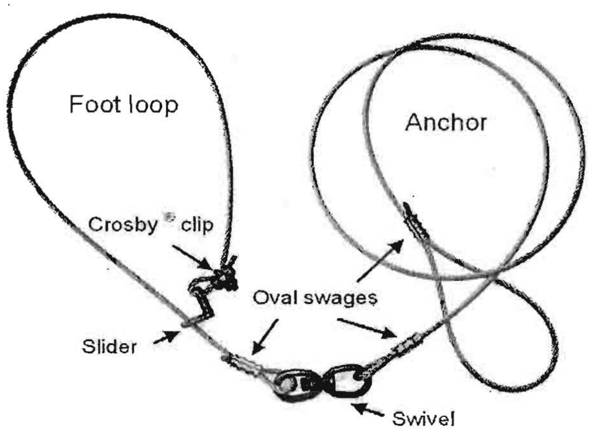

Fig. 3. A complete bear snare showing foot loop and anchor sections connected by a 0.794 cm swivel.

The cable ends were welded in tests 1 through 6. Tests 7 and 8 focused on components used in the anchor section of a snare cable. Test 7 consisted of swaged loops on the cable ends with swaged loops connecting to either end of the swivel, and test 8 consisted of 2 swaged loops on either end of the cable.

Cycled pull tests

We performed 4 additional tests (9–12) using a series of cycled or repeated straight pulls (Table 2). Test 9 used the snare configuration from test 1 and involved 10 pulls with a mean of 17.3 kN and a range of 15 kN to 19.4 kN. Tests 10–12 involved cycled pull tests on various snare configurations using the following procedure: the snare assembly was pulled to the point of imminent failure, tension was temporarily removed, and the pull was repeated until complete failure occurred.

Results

Pull test

Single pull tests 1, 2, and 3 (n = 26) resulted in cable failures adjacent to the slider at forces between 22.8 kN and 29.7 kN (Table 1). Given that all 3 assemblies resulted in failure at the same point, a Weibull statistical analysis of the pooled results was conducted. We fit the failure loads for all 26 tests to a Weibull distribution using both least squares (Fig. 4) and the maximum likelihood method. Both methods yielded a shape parameter (Weibull modulus) of 17.6 and a scale parameter of 27.2 kN, with

Table 1. Pull test of cable and components until failure of system, in kilonewtons (kN). Tests 1–6 are of foot loop systems; tests 7–8 are of standard anchor components. Parts 5 and 8 (Snare setup) are potential weak links. Mean and SE not calculated for sample sizes of <4.

Test	n	Snare setup[b]	Failure location[a] (n)	Force, kN Range[c]	Mean/SE
1	13	2, 3, 4, 6, 9, 10	A (13)	22.8–28.7	25.9/0.48
2	8	2, 3, 4, 7, 9, 10	A (8)	25.6–29.7	27.4/0.51
3	5	2, 3, 10, 12	A (5)	23.4–28.2	26.2/0.83
1 + 2 + 3	26		A (26)	22.8–29.7	26.4/0.34
4	8	2, 3, 5*, 6, 8*, 10	A (5)	11.0–27.2	20.49/2.59
			B (3)		
5	3	2, 3, 5*, 6, 9, 10	A (2)	14.5–26.6	
			B (1)		
6	3	2, 3, 4, 6, 8*, 10	A (2)	12.6–27.1	
			C (1)		
4 + 5 + 6	14		A (9)	12.6–27.2	20.9/1.08
			B (5)		
7	8	2, 1, 13, 1, 2	E (7)	30.8–32.6	31.5/0.21
			F (1)		
8	3	2, 2	E (3)	33.4–33.5	
7 + 8	11		E (8)	30.8–33.5	32.0/0.31
			F (1)		
			G (2)		

[a]Failure location: A = 7 x 19 galvanized aircraft cable at slider, B = cable slip through small clamp, C = cable slip through Crosby® clip, D = cable at entry point to Crosby® clip, E = cable adjacent to swage, F = swivel, G = cable at bight on swivel.
[b]Snare setup components: 1 = swaged loop at swivel, 2 = swaged loop, 3 = angle-iron slider, 4 = Crosby® clip, 5 = small clip, 6 = dead horse 7 = live horse, 8 = hand torque, 9 = torque to 20.3 Nm, 10 = welded cable end, 11 = unwelded cable end, 12 = swaged loop at slider, 13 = swivel.
[c]Force applied in kiloNewtons (kN).

Table 2. Cycled pull tests of cables and components. Test 9 was cycled to predicted potential force of captured bear. Tests 10, 11, and 12 were pulled to failure. Components 8 and 11 (Snare setup) are potential weak links.

			Cycles		Force, kN
Test	*n*	Snare setup[a]	(*n*)	Failure location[b]	Range[c]
9	1	2, 3, 4, 6, 9, 10	10 (1)	No failure	15.0–19.4
10	3	2, 3, 4, 6, 9, 10	2 (2)	A	23.9, 24.0
			3 (1)	A	23.9
11	3	2, 3, 4, 6, 9, 11*	3 (1)	A	24.7, 26.3
			4 (1)	A	
			4 (1)	C	20.9
12	3	2, 3, 4, 6, 8*, 11*	3 (3)	C	19.9, 24.0, 24.7

[a]Snare setup components: 1 = swaged loop at swivel, 2 = swaged loop, 3 = angle iron slider, 4 = Crosby® clip, 5 = small clip, 6 = dead horse, 7 = live horse, 8 = hand torque, 9 = torque to 20.3 Nm, 10 = welded cable end, 11 = unwelded cable end, 12 = swaged loop at swivel.
[b]Failure location: A = 7 x 19 galvanized aircraft cable at slider, C = cable slip through Crosby® clip.
[c]Force applied in kiloNewtons (kN).

98% and 99% variance explained, respectively, for the 2 methods. A Weibull survival plot (Fig. 5) of the pooled data from test sequences 1, 2, and 3 illustrates our main results, where the survival is defined as 1 minus the probability of failure at a given load. The dashed line indicates our 16.8 kN benchmark. We also calculated survival percentiles from the data based on the methods of Barbero et al. (2000). This analysis gave a 90th percentile of 23 kN and a 99th percentile of 19 kN, at the 95% confidence level.

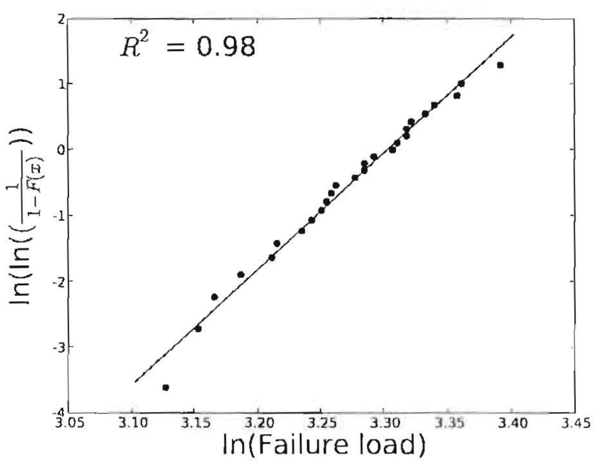

Fig. 4. Weibull plot of failure loads from test sequences 1, 2, and 3, which all failed in the cable adjacent to the slider. $F(x) = (i - 0.5)/(n + 0.4)$ is the rank order failure estimator with i = rank, in ascending order, and n = 26 = number of observations. The least squares fit gave 1 of the 2 independent methods of estimating the Weibull parameters used in this study.

In test sequence 4 when generic clamps were hand-tightened, 5 cable failures occurred at the slider and 3 failures occurred as the cable slipped through the clamp at forces of 11.0, 12.0 and 12.1 kN. When generic clamps were torqued to 20.3 Nm, 2 cable failures occurred at the slider and one failure (14.5 kN) occurred as the cable slipped through the clamp. In test 6 we observed one instance where the cable slipped through the hand-tightened Crosby® clip at 12.6 kN. The other failures occurred in the cable at the slider. When the cable failed at the slider in tests 4, 5, and 6, slider forces were in excess of 21.3 kN. The failure range and 2 SE for tests 1–6 (Fig. 6) indicates failures in those snare configurations, with weak links, that are below the threshold of 16.8 kN. In test sequences 7 and 8, where anchor cables and components were examined, all 11 replicates failed in excess of 30.8 kN (Table 1).

Cycled pull tests

The snare used in test 9 maintained integrity with only slight deformation of the slider and the swivel. In test 10, all failures occurred in the cable at the slider at forces above 23.9 kN. In one instance in test 11 and all 3 instances in test 12, the cable slipped through the clip at forces greater than 19.9 kN.

Discussion

While we can't predict the exact forces a bear may exert on a snare assembly, we suggest a benchmark of 16.8 kN as a minimum force that snares must withstand in pull testing. We provide estimates of the range of failures for typical snare components, and

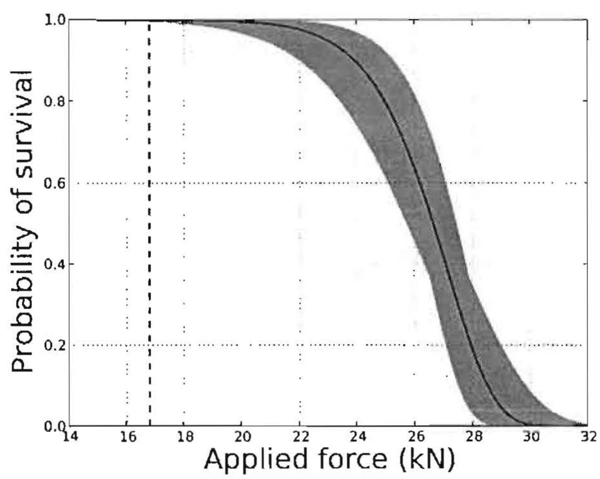

Fig. 5. Weibull survival plot for the pooled data from test sequences 1, 2, and 3 ($n = 26$). The survival is defined as 1 minus the probability of failure at a given load. The dashed line indicates our 16.8 kN threshold. The shaded area includes the 95% confidence interval for the mean of the recommended configuration.

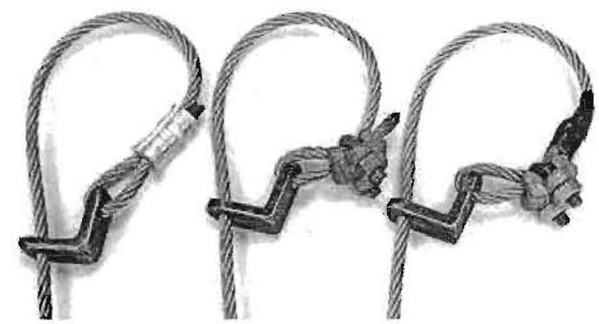

Fig. 7. Most reliable foot loop configurations for withstanding forces >16.8 kN. Left: aluminum sleeve; middle: dead horse Crosby® clip; right: live horse Crosby® clip.

where failures occurred during tests. The most reliable foot loop systems we tested consisted of a Crosby® clip torqued to 20.3 Nm in a dead horse or live horse configuration, with welded ends or a swaged loop at the slider (Fig. 7). With these 3 configurations, all failures occurred with the cable breaking as the slider deformed while compressing on the simulated bear leg at forces >22.8 kN. These values are comfortably above the 16.8 kN benchmark we used in this study. While the live horse Crosby® clamp configuration failed at slightly higher force (Table 1), some cable slippage occurred at higher forces. Because cable failure occurred in the dead horse configuration (and not cable slippage), this configuration also appears to be a strong and reliable option while minimizing injury to the bear.

The generic cable clamps yielded inconsistent results when hand-tightened or tightened with a torque wrench (Table 1). The Crosby® clips were inconsistent only when hand-tightened (Table 1, 2). The unwelded cable end in the cable clamps had inconsistent strength when tested on both Crosby® clips and generic clamps (Table 2). Aluminum compression sleeves used to join 2 cables into a loop never failed.

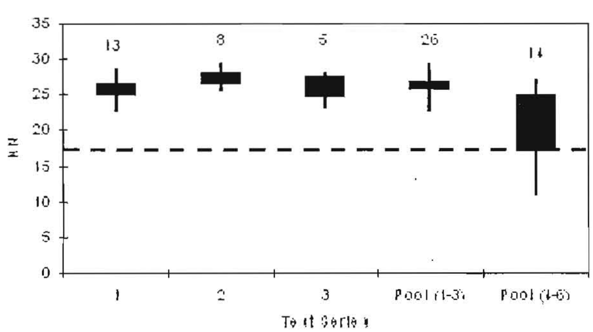

Fig. 6. Box plots of the range of failures in kilonewtons (kN) for snare foot loops. Vertical lines are the range and the boxes represent ±2 SE. Tests series 1, 2, and 3 are recommended systems and data is pooled in the 4th box. The 5th box has weak links within the system and represents tests 4, 5, and 6 pooled. The horizontal dashed line is the threshold (16.8 kN) that snares should exceed in pull tests. Sample sizes are above boxes.

Recommendations

There are several snare assemblies that appear to be comparable, and given our tests, provide a consistent failure range in excess of 16.8 kN. However, it must be recognized that a large bear may exert forces >16.8 kN on a snare. We recommend the following components be used in constructing snares:

- Galvanized aircraft cable (7 x 19 strands, 0.635 cm diameter) with a manufacturer's rated breaking strength of 3,175 kg. The safe working load (SWL) at 5:1 is 630 kg. The working load at 1,710 kg (16.8 kN) is 1.8:1 and exceeds the SWL by 2.7 times.
- Aluminum or copper oval compression sleeves. These are rated between 70% and 100% of cable strength (F. Maraz, Nicopress® Product Quality, Cleveland, Ohio, USA, personal communication, 2007).

- Swivels (0.794 cm) have a manufacturer rated breaking strength of 2,812 kg and a SWL at 5:1 of 576 kg. The working load at 1,710 kg is 1.6:1 and exceeds the SWL by 3 times.
- A 2.0-cm section of angle iron, 3.81 cm x 3.81 cm x 0.635 cm, with edges smoothed, should be used for sliders.
- Crosby® Clips (Model G-450; 0.635 cm) are rated at 80% of cable strength if torqued (20.3 Nm) to specification (D. Conner, Crosby Group Product Technician, Tulsa, Oklahoma, USA, personal communication, 2007). We believe that smaller generic clamps should never be used in snare assemblies.

The following system should be used to construct the snare assembly to maximize holding power and still have a foot loop that efficiently throws when the spring is released. Aluminum or copper oval compression sleeves should be used at both ends of the anchor cable and at the static end of the foot loop where it attaches to the swivel (Fig. 3). We recommend leaving enough space in the swivel loop at the foot loop end of the anchor cable to allow the fork of the spring to be inserted. Enough cable must be pulled through the sleeve to ensure at least 0.95 cm is exposed after the sleeve expands during crimping (Loos & Co. Cableware Division 2007, National Telephone Supply Co. 1997). Sleeves should be crimped a minimum of 3 times (National Telephone Supply Co. 1997). Three configurations may be used to secure the loop end to the slider. The second option is a Crosby® clip in a live horse configuration with the tail end on the inside of the loop (taped to prevent the cable end from damaging the bear's foot). The third option is a Crosby® clip in a dead horse configuration (Fig. 7). Tail ends must be welded when using the Crosby® clips to preserve the rounded shape of the cable. When properly assembled, all failures using these configurations occurred within the cable. When torquing the Crosby® clips to 20.3 Nm, nuts must be tightened alternately to ensure equal length of exposed threads. Torque should be checked prior to each capture session.

It is still possible to adapt the snare to lessen injury to restrained bears without compromising the integrity of the snare. Adaptations to reduce injury include adding springs to the anchor cable (Johnson and Pelton 1980) and various cub stops and anti-abrasion devices on the foot loop (Jonkel 1993, Lemieux and Czetwertynski 2006).

Acknowledgments

We thank M. Proctor and T. Radandt for many hours of thoughtful conversation around the campfire providing the impetus to conduct these tests. They also provided helpful comments on the manuscript. We also thank the editors and others who reviewed and made useful comments greatly improving the manuscript. K. Mauthner and Basecamp Innovations Ltd. were invaluable in providing the technical expertise and facilities to conduct our tests. Lastly, we acknowledge and thank "Kidd" who had the courtesy to keep on going when he broke out of the snare.

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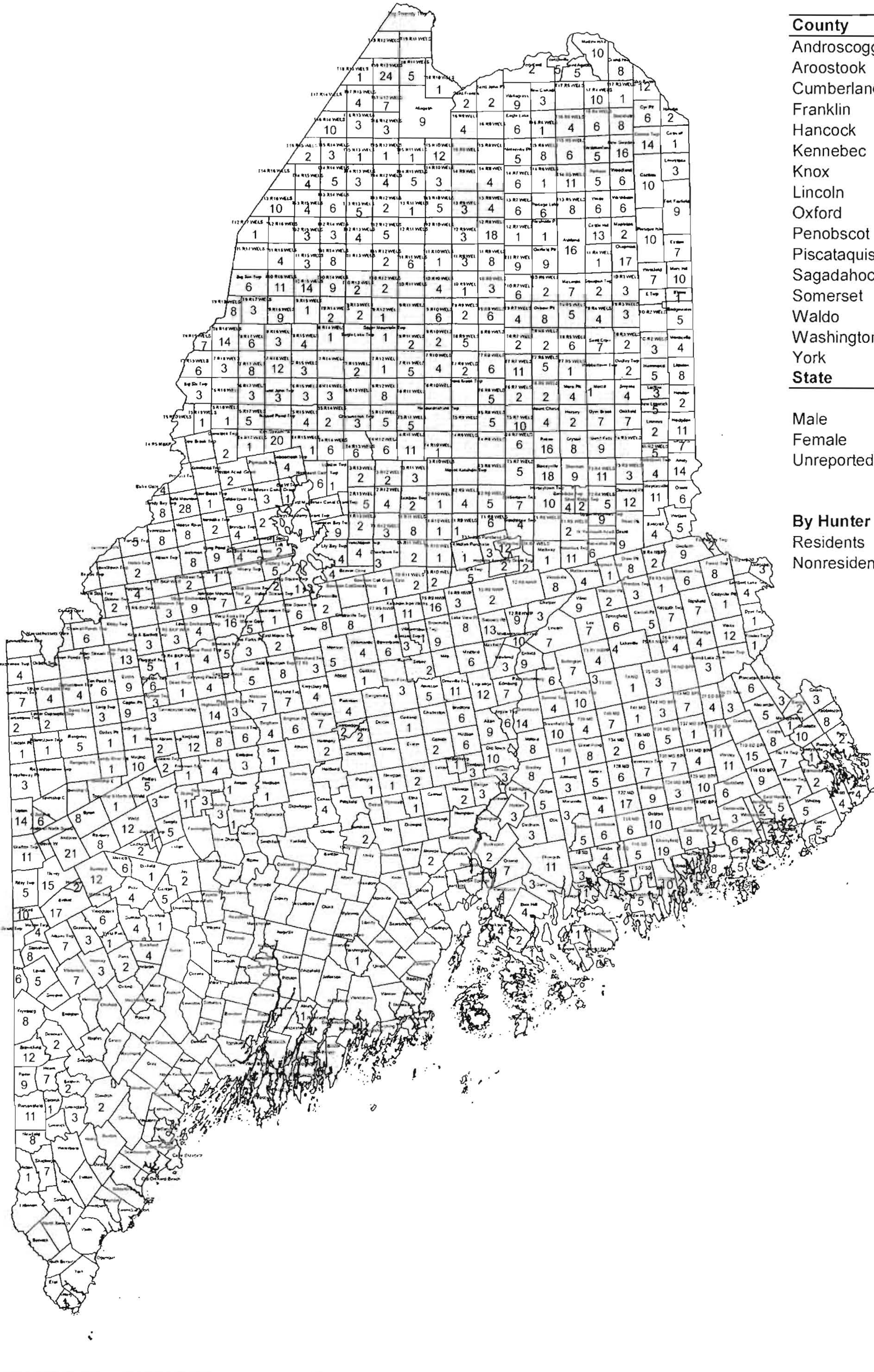
2010 Bear Harvest by Town



County	# of Bears
Androscoggin	0
Aroostook	875
Cumberland	4
Franklin	132
Hancock	157
Kennebec	0
Knox	1
Lincoln	1
Oxford	268
Penobscot	425
Piscataquis	357
Sagadahoc	0
Somerset	441
Waldo	4
Washington	365
York	32
State	**3,062**

Male	1,699
Female	1,329
Unreported	34

By Hunter Residence

Residents	1,199
Nonresidents	1,863

Maine's 2010 Black Bear Season

The general hunting season for black bear in 2010 opened August 30 and closed November 27. Hunters were allowed to hunt bears near natural food sources or by still-hunting throughout this 3-month period. Hunting over bait was permitted from August 30 through September 25. The hound season overlapped the bait season, opening September 13 and closing October 29. The bear trapping season opened September 1 and closed October 31.

In 2010, 2,479 bears were taken over bait (81%), 352 bears were taken by hound hunters (12%), 87 bears were taken in traps (3%), 77 were taken by unreported methods (3%), and 67 bears (2%) were harvested by deer hunters. Most bears were taken early in the season with 2,797 bears (91%) harvested before the end of September. Although the 2010 harvest of 3,062 bears is lower than last year's harvest of 3,486 bears, it exceeded the previous 4 year harvest (2,659-2,879).

In Maine, the abundance of fall foods for bears is high in even numbered years and low in odd number years which influence the numbers of bears harvested by hunters especially late in the season. This year, the exceptionally early spring caused summer and fall fruit and nut crops to ripen early, as a result bears entering their dens earlier than expected and few bears were killed by deer hunters.

Geographic Distribution of the Harvest
Bears were harvested in all 29 Wildlife Management Districts (WMDs). The density of harvest expressed as the number of bears killed per 100 square miles of habitat (forested land) was greatest in WMD 28 at 24 bears/100 mi^2 followed closely by WMDs 3, 6, 11, and 12 with 18 to 20 bears harvested/100 mi^2. In all other WMDs, hunters harvested less than 17 bears/100 mi^2 (statewide average of 10 bears/100 mi^2). Bears were harvested in 13 of the state's 16 counties. Most (875) were harvested in Aroostook county accounting for 29% of the harvest. No bears were taken in Androscoggin, Kennebec, and Sagadahoc counties and <5 bears were taken in Cumberland, Knox, Lincoln and Waldo counties.

Residence of Successful Hunters
Maine's reputation for producing high-quality bear hunting was again reflected in the harvest distribution by hunter residency. Visitors to Maine killed 1,863 bears (61%) of the 3,062 bears tagged during 2010. Non-resident hunters shot most of the bears (65%) taken over bait and with the use of hounds (61%), although bait hunting remained popular amongst resident hunters with 73% of successful resident hunters taking their bear over bait. Although few bears were taken during the deer season or in traps, Maine residents accounted for the majority (88% and 85%, respectively) of the bears taken during those seasons.

Assistance by Registered Maine Guides
In 2010, guides helped take 79% of bears harvested over hounds, 67% of the bears taken over bait, 23% of trapped bears, 20% of the bears for which method of take was unreported, and none of the bears taken by deer hunters. Guides assisted 254 residents (23%) and 1,632 nonresidents (91%) with their successful hunts in 2010.

Sex and Age Distribution of the Harvest
Males made up 56% (1,699 bears) of the 2010 harvest. Adult bears accounted for 91% (2,797 bears) of the harvest and sex and age were not reported for an additional 34 bears (1%).

Prospects for the 2011 season
The Department has adopted a generic bear season framework to maintain consistent hunting periods, unless management concerns require changes to the lengths of hunting or trapping periods. In 2011, the season will remain similar to those in recent years. The season will span 13 weeks and will begin on the last Monday in August and close on the last Saturday in November (August 29-November 26, 2011).

A population model of Maine black bears indicates the population can sustain a harvest of 15%. Thus a harvest of 3,500 bears was needed to stabilize Maine's bear population conservatively estimated at 23,000 bears in 2004. However, in recent years we have not met our harvest objective. This low harvest rate coupled with high cub survival rates has allowed Maine's bear population to grow. In the next year, we will be considering modifying hunting opportunities to stabilize Maine's bear population based on a pending updated population estimate.

A PASSIVELY TRIGGERED FOOT SNARE DESIGN FOR AMERICAN BLACK BEARS TO REDUCE DISTURBANCE BY NON-TARGET ANIMALS

STEVEN R. REAGAN, U.S. Fish and Wildlife Service, Mandalay National Wildlife Refuge, 3599 Bayou Black Drive, Houma, LA 70360, USA, email: Steve_Reagan@fws.gov
JANET M. ERTEL, U.S. Fish and Wildlife Service, Mandalay National Wildlife Refuge, 3599 Bayou Black Drive, Houma, LA 70360, USA, email: Janet_Ertel@fws.gov
PAT STINSON, U.S. Fish and Wildlife Service, 6578 Dogwood View Parkway, Suite B, Jackson, MS 39213, USA, email: Pat_Stinson@fws.gov
PAUL YAKUPZACK, U.S. Fish and Wildlife Service, Mandalay National Wildlife Refuge, 3599 Bayou Black Drive, Houma, LA 70360, USA, email: Paul_Yakupzack@fws.gov
DON ANDERSON, U.S. Fish and Wildlife Service, Tensas National Wildlife Refuge, 2312 Fred Morgan, Sr. Road, Tallulah, LA 71282, USA

Abstract: American black bears (*Ursus americanus*) are commonly captured throughout their range for research or management purposes. However, with the most commonly used capture devices, capture of non-target animals and disturbance of traps can substantially reduce capture efficiency. Here, we describe a passively-triggered snare designed to capture black bears and reduce such trap disturbance. The passively triggered snare system was designed to secure the snare to the foot of the bear as it attempts to access bait in the bottom of a hole by hooking a screen on top of the bait with its claws, pulling a PVC tube upward and gently tightening the snare to its wrist. We qualitatively compared this design (143 trap-nights) with 2 conventional methods, spring-activated snares (574 trap-nights) and culvert traps (129 trap-nights). Passively-triggered snares captured bears 15 of 74 times (20%) the traps were disturbed, spring-activated snares 22 of 360 times (6%), and culvert traps 25 of 63 times (40%). Both the passively-triggered snares and culvert traps prevented lost trap-nights to non-target species, such as raccoon (*Procyon lotor*). Passively-triggered snares prevented bear cubs from being captured, although several were observed attempting to take bait from the sets. Passively triggered snares, like culvert traps, require no concealment, but unlike culvert traps, are highly portable. The passively-triggered snare provides the same advantages as other snare designs, but has the potential to increase capture efficiency when disturbance by non-target animals is common. The results of our study suggest further evaluation of this technique is warranted. Comparisons with other techniques should be based on equal number of trap-nights and a study design that incorporates different environmental conditions.

Ursus 13:317–320 (2002)

Key words: Aldrich foot snare, American black bear, animal safety, capture efficiency, capture injury, culvert trap, non-target species, trap design, *Ursus americanus*

Wildlife managers and researchers often use culvert traps and Aldrich foot snares to capture American black bears. Culvert traps were designed in the early 1900s primarily to capture nuisance bears in national parks (Erickson 1957). Culvert traps have withstood the test of time, and various styles and modifications of this trap design remain in use. Because culvert traps are difficult to move, their use is generally restricted to areas near roads. The primary advantage of culvert traps compared with snares relate to human safety; culvert traps can be safely used in areas frequented by people and captured bears can be transported or released without the need of immobilization.

The Aldrich foot snare with its spring-activated trigger has been used widely as an alternative trap design since its development by a Washington Forest Protection Association hunter, Jack Aldrich, in the 1960s (Poelker and Hartwell 1973). This trap provides a safe and effective capture method for black bears in a variety of field conditions (Johnson and Pelton 1980). Bait generally is used with both traps to attract bears to trap sites.

Baits can attract numerous non-target animals to trap sites. Trap efficiency can be greatly reduced by non-target animals exposing or disabling traps while attempting to remove the bait. Reduced capture efficiency is of particular concern in areas with relatively low bear densities and high densities of non-target species. Moreover, the capture of non-target animals is generally undesirable and has received more public scrutiny in recent years. Our objective was to develop a passively triggered trap that would be less sensitive to disturbance by non-target species, but comparable with other trapping methods in terms of bear and human safety and efficiency.

STUDY AREA

Trapping efforts were focused within the upper Tensas and the coastal Atchafalaya River Basins in Louisiana. The study area in the Tensas River Basin (Deltic Tract study area) was approximately 30 km^2 and consisted of small, isolated tracts of bottomland hardwood forest surrounded by large expanses of agricultural land. Primary agricultural crops included soybeans, cotton, rice, corn, wheat, and sorghum. In the coastal Atchafalaya River Basin, a 80-km^2 area of drained cypress–tupelo (*Taxodium distichum–Nyssa aquatica*) and bottomland hardwood forest was trapped. Only a small proportion of the habitat was associated with agriculture, primarily in the form of sugarcane.

METHODS

Three trapping methods were used to capture black bears from 14 April to 27 September 2000: modified Aldrich snares with a passive trigger, modified Aldrich snares with a spring-activated trigger, and culvert traps. Our intent was not to rate the efficiencies of the different traps because we could not control for the individual effects of the trappers, effort, or sites within which traps were set. Thus, comparisons of effectiveness among trap types are for general reference only.

Passively-triggered Aldrich snares consisted of the snare design described by Johnson and Pelton (1980). We replaced the standard spring-activated trigger with a passive trigger designed to secure the snare to the foot of the bear as it attempts to access the bait in the bottom of an earthen hole by hooking a screen on top of the bait with its claws, pulling the entire tube upward and gently tightening the snare to its wrist.

The passive trigger was made from two 15.2-cm diameter schedule-40 (0.6 cm wall thickness) PVC (polyvinyl chloride) pipe sections. The sections were joined top to bottom and placed into an earthen hole of equal diameter and deep enough to leave the top of the pipe flush with ground level (40 cm). We found that a standard post-hole digger provided a neat and efficient method to prepare the earthen hole. The lengths of the top and bottom sections measured 10.2 cm and 27.9 cm (Fig. 1), respectively, and corn bait was placed under a 1.3- x 1.3-cm wire screen fixed into the bottom of the joined PVC pipes (Fig. 2). The dimensions of the trigger reduced the potential for jaw captures. The upper edge of the top section of PVC-pipe was beveled inward, thereby discouraging bears from standing on the lip of the pipe while investigating the bait.

Fig. 1. Unassembled passive trigger designed to be used with the modified Aldrich foot snare for the capture of black bears.

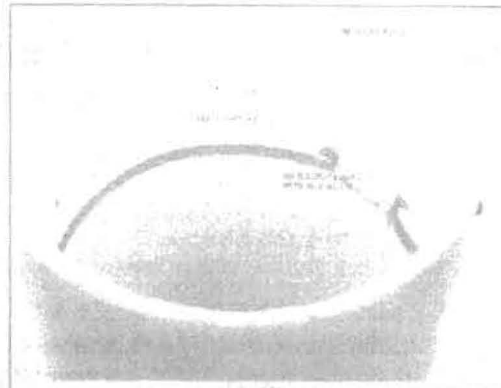


Fig. 2. The fixed bait screen inside the bottom of the trigger protects the bait from non-target species while providing a clawing surface for bears (passive trigger fully assembled).

Both sections received a matching and adjoining notch and groove; these features both concealed and retained the snare loop and angle iron (Fig. 3). Each notch had a depth of 1.3 cm and length of 10.2 cm. Both interior and exterior edges associated with the notch were rounded to allow smooth snare movement during triggering. The groove was along the full circumference of the pipe's interior and had a height of 0.3 cm and a depth of 0.5 cm., with both the top and bottom sections having a rabbet of 0.15 cm height and 0.5 cm depth. Duct tape was used to secure the sections together, thereby matching the top and bottom notches and grooves without covering the notch.

We ensured proper closure of the snare by using a 4D nail (3.8 cm length) as a pin to secure the snare's angle iron to the trigger. The upper 2.5-cm length of the nail was pressed into a 'U' shape. The cable's eye, used to hold the angle iron on the cable, was placed over the pin (Fig. 4). The remaining length of the pin was inserted into a small hole drilled in the center of the bottom notch. An additional cable clamp was placed along the snare loop just behind the angle iron. When the snare was set, this

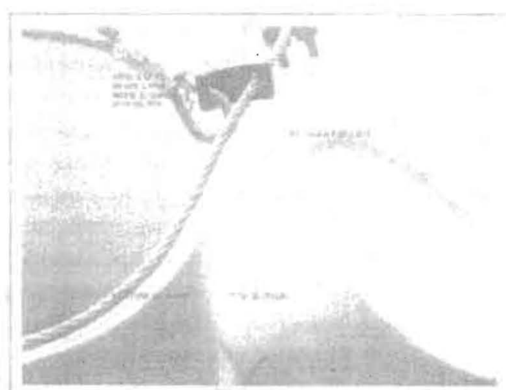


Fig. 3. The passive trigger's top edge is beveled and the snare cable is hidden and secured using a wall groove and 4D-nail pin (passive trigger fully assembled).

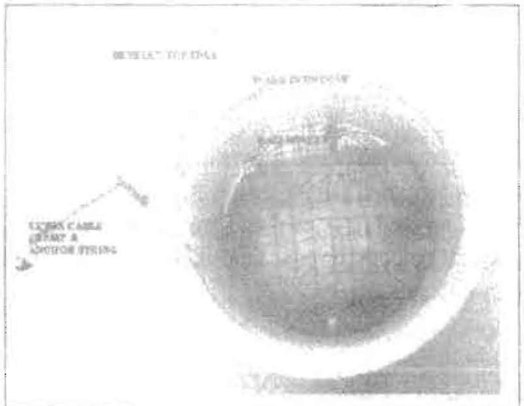


Fig. 4. The 4D nail placed within the eye of the cable secures the angle iron to the passive trigger (passive trigger partially assembled).

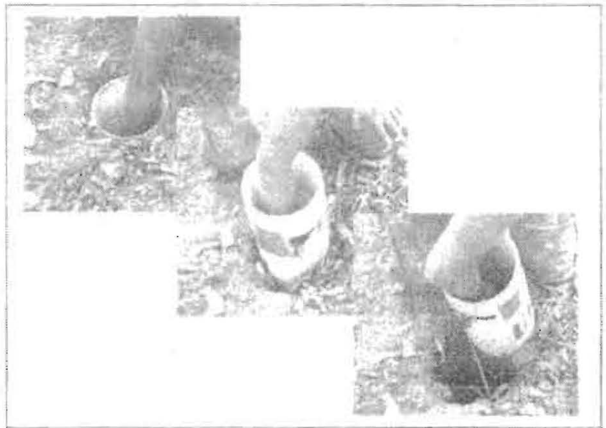


Fig. 5. The passive trigger closes the snare's loop when the PVC pipe is pulled out of the ground by hooking the screen fixed within the bottom of the pipe.

clamp was attached using nylon string to an anchor placed 12 cm down the wall of the earthen hole. The string between the snare cable and anchor was securely tightened by tightening the cable clamp on to the string when the string was pulled snug. The attached anchor, a welding rod, provided the resistance necessary to close the snare but gave way once the bear was captured (Fig. 5).

Spring-activated modified Aldrich foot snares were used as described by Johnson and Pelton (1980). Trees and heavy brush that could potentially bind snare movement of trapped bears were removed. However, light brushy vegetation, used to construct trap cubbies and direct the movements of approaching bears, remained within the snare circle. Bait was hung in the area of the trap and placed as an enticement behind the trap.

Culvert traps were constructed from corrugated aluminum culvert pipe with a 91-cm exterior diameter and a total length of 213 cm. One end of the culvert was blocked using 1.9-cm No. 9 raised expanded steel. The entrance consisted of an aluminum plate door of 0.6 cm thickness. Bait was attached to a trigger at the rear of the culvert. Additional bait was either hung or placed on the ground near the front of the culvert.

All traps were placed in well shaded areas and in areas receiving little human disturbance. All traps were checked daily.

RESULTS

A total of 143, 574, and 129 trap-nights were accumulated using passively triggered snares, spring-activated snares, and culverts traps, respectively (Table 1). Trapping efficiency, measured by trap-nights/bear was greater for passively triggered snares than spring-activated snares, but less than culvert traps (Table 1). Each trap design captured individual bears more than once.

Spring-activated snares were responsible for 1 hind-foot capture, 1 toe-capture, and 1 catch part way up the leg. The passively triggered snares placed the snare loop consistently between the interdigital and metacarpal pads on the front foot, except in 2 cases when the catch was on the posterior side of the interdigital pad. Capture-related injuries included minor cuts and abrasions to feet, 1 broken incisor, and 1 severely torn toe and front pad (Table 1). The broken tooth and the severely torn toe were for 2 bears captured with the spring-activated foot snares.

DISCUSSION

Capturing black bears can be challenging because bears quickly become trap smart and learn to avoid capture. The resulting decrease in capture efficiency is exacerbated when non-target species interfere and disable traps prior to a bear's visit. We developed the passively-triggered

Table 1. Summary of effort and capture success of American black bear with passively triggered snares, spring-activated snares, and culvert traps, upper Tensas and coastal Atchafalaya River Basins, Louisiana, April–September 2000.

Trap type	Trap nights	Bears captured	Trap-nights/bear	Traps triggered	Ratio: caught bears/triggered trap	Injuries
Passively triggered snare	143	15	9.5	74	0.20	3 (20%)
Spring-activated snare	574	22	26.1	360	0.06	8 (36%)
Culvert trap	129	25	5.2	63	0.40	2 (8%)

snare to safely capture target bears and to prevent non-target species or bear cubs from taking the bait or tripping the trap. Our trigger design allowed medium-sized mammals, such as raccoons and bear cubs, to investigate the bait without triggering the trap. The trigger requires a long forearm reach and a direct pull upward on the bait screen to close the snare loop. Small animals were unable to both reach the screen and to exert the strength required to pull the pipe from the ground and tighten the snare; although we observed several attempts by cubs to take the bait, the trap sets remained undisturbed. Because passively triggered snares prevented disturbance by non-target animals, the number of opportunities to capture bears increased. In contrast, spring-activated snares were frequently disturbed by non-target animals. Culvert traps demonstrated the greatest capture success, but site selection required vehicle access. Both snare systems allowed greater flexibility in site selection.

The passive trigger provided consistent catches behind the interdigital pad of the front foot. Thus, this trap design may increase handler safety by eliminating toe and hind-foot captures. As an additional advantage, passively triggered snares required no concealment or structural materials. Such materials may be one cause of injuries to captured bears. Although our sample sizes are low and the study was not designed to compare injury rates among the 3 methods, our preliminary data suggests that injuries may be less severe and less frequent with the passively-triggered snare.

Techniques that prevent capture of non-target animals are valuable. Capturing non-target animals could present conservation and management concerns when the captured animals are endangered or game species. Even captures of nuisance species, such as raccoons, can raise concern with the general public and usually these concerns need to be addressed in animal welfare protocols.

Our observations indicate that passively triggered snares can capture black bears and prevent the capture of non-target animals, thereby increasing capture efficiency. The passively triggered snares seemed as effective as spring-activated foot snares for capturing bears. We believe the passively triggered snare merits further testing based on studies designed to assess its effectiveness under various environmental conditions, among different trappers, and within different regions.

ACKNOWLEDGMENTS

We are thankful to the many private landowners who provided access to their properties, Louisiana's Trial Lawyers Association, and U.S. Fish and Wildlife Service for funding, and for comments from the reviewers that were both well intentioned and constructive.

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Bear Trapping

There is an open season on trapping bear from September 1 through October 31 annually. You are allowed to take one bear by trapping and one bear by hunting each year (**new law as of 9/28/2011**—see New Laws Enacted in 2011). See also Bear Hunting Regulations. You must obtain a trapping license and a bear trapping permit to take a bear by trapping.

If you trap for black bear you are required to follow the same general rules that apply to the labeling of traps, the tending of traps and the need to obtain landowner permission. If you trap a bear, you are required to follow the same transportation and registration rules as apply to bear which have been taken by hunting. In addition, you are required to follow other rules which apply specifically to bear trapping, as follows:

You are **not** allowed to have more than one trap set for bear at any time.
The **only** types of traps you are allowed to use when trapping for bear are the cable trap (foot snare), and cage type live trap.
If you use a cage-type live trap, you **must** enclose the trap, as follows:
the trap **must** be enclosed by at least 2 strands of wire, one strand 2 feet from the ground and one strand 4 feet from the ground;
the wire **must** be held securely in position;
the wire **must** always be at least 5 yards but not more than 10 yards from the trap;
the enclosure **must** be plainly marked with signs that say "BEAR TRAP" in letters not less than 3 inches high; and
the signs **must** be securely fastened to the top strand of wire **and** be spaced around the entire enclosure not more than 20 feet apart.
If you use a **cable trap**, the trap **must** have a closing diameter of not less than 2½ inches.
Whenever cable traps (foot snares) are used to trap for bear, each trap must be set at or below ground level in such a manner as to catch the animal only by the foot or leg.
All bear traps **must** be tended at least once each day.
You are **not** allowed to catch a bear in a trap and allow another person to kill or register the bear.
You are **not** allowed to continue to trap for bear after you have already killed or registered one in a trap.
Bears caught in traps must be killed or released and not moved away from the catch site. A bear caught in a trap may not be used in conjunction with a hunt or to train a dog for bear hunting.
The same rules apply to hunting and trapping for bear with the use of bait. (See rules about the use of bear baits.)
A line of demarcation of at least 500 yards shall be established at sites permitted or licensed for the disposal of solid waste. A person may not trap within the demarcation area (except that an agent of the commissioner is exempt for the purpose of live trapping of nuisance bear).

2010 MDIFW Black Bear Trapping Season Summary
Prepared by Randy Cross, Wildlife Biologist, MDIFW

As part of MDIF&W's ongoing black bear monitoring project, a team of biologists captured bears using foot snares northeast of Beddington this spring.Our team included MDIF&W wildlife biologist, Randy Cross, field crew leaders, Dan Wagner and Craig McLaughlin, wildlife field technician (contractor), Marcus Mustin with volunteers, Jared Mitchell, Everett Smith and Susan Bard.

We attempted to recover 6 GPS collars which had quit transmitting a signal as well as bolster the number of radiocollared females which are monitored to represent all bears living in similar habitats in the region. The GPS collars also had stored up to 900 locations from each bear's movements last year.

This spring came very early (many indicators were about 3 weeks ahead of average). Bears in this area entered their dens early last fall and many were lean this spring, resulting in active baits early with continued high interest through the trapping period. Weights of yearlings in their winter dens are our best indicator of the relative abundance of food the previous summer. Yearlings in last winter's dens here averaged 37 lbs. This is 16 lbs less than yearlings in our central Maine study area and 8 lbs lighter than yearlings in our northern study area last winter.

We began tending snares on May 13 and continued 43 days to June 24. We set traps at 92 sites, mostly in Townships 35 and 36 with a few sites in the very southernmost portions of T41 and T42 (under 50 sq miles). We captured twice as many males as females (65 male captures / 34 female captures – 99 in all). This 2:1 ratio of male to female captures is normal, even though there are more females than males in the population due to hunter selection of larger male bears, reluctance to harvest females with cubs and male bears' higher vulnerability to harvest. Males tend to be more vulnerable to snares set for research as well, due in part to their extensive traveling during breeding season (mostly, late May through July). We captured 72 different bears of which 28 were new to the study and 44 were previously tagged.

Twelve yearlings (9M, 3F) were captured 23 times.Bears identified as yearlings are about 15 months old with most weighing between 36 and 45lbs this spring in this area. Male yearlings tend to be a bit heavier than female yearlings and, as with adults, are easier to catch. Their inexperience and vulnerability to capture is well illustrated by one male yearling that was captured 5 times and his brother was captured 3 times (these two were bigger than the average weighing near 70 lbs each). We've found that many of the females in this area are reproductively synchronized – producing cubs on odd years and accompanied by yearlings in the spring during even years. We witnessed similar synchronous cub production in our northern study area (west of Ashland) during the 80's and 90's. Consequently, it wasn't surprising that we caught no lactating females or cubs this spring.

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As part of our ongoing effort to monitor reproduction in the area, we placed radiocollars on 16 females that either had no collar or had nonfunctioning collars, ending the season with 42 active collars on female bears, including 3 bears with GPS collars. This spring, we also captured 5 of the 6 bears whose GPS collars were not transmitting. We are using GPS collars to calculate the density of bears on this study area, The reliability of our density estimate is limited by our ability to capture the majority of the bears in the focus area. This spring was a particularly successful trapping season, as we captured 19 of 31 collared females (61%) known to inhabit the area that we trapped. We last trapped in this area in the spring of 2008.

An interesting side note, we caught 4 males over 300 lbs, one of which was over 21 years old (365 lbs). These bears will most likely gain somewhere near 200 lbs before entering their dens in late November. These older males are impressive, but as usual, around 70% of the bears captured weighed less than 150 lbs. The total weight of 99 captures was just over 13,000 lbs averaging less than 135 lbs per capture. On 5/26 we caught 5 bears totalling 1,251 lbs. We also collected 72 hair samples which may be used for genetic or physiochemical analysis.

Our monitoring of black bears on 3 study areas in northern, central, and eastern Maine helps us assess if we are meeting black bear population goals for conserving Maine's bear population, providing future viewing and hunting opportunities, and minimizing conflicts with bears. To learn more about black bears in Maine, visit http://www.maine.gov/ifw/wildlife/species/index.htm.

BLACK BEAR MANAGEMENT SYSTEM AND DATABASE

NOVEMBER 1990

Maine Department of Inland Fisheries & Wildlife
Wildlife Resource Assessment Section
Mammal Group

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PART I. – BLACK BEAR MANAGEMENT SYSTEM

INTRODUCTION

This document describes the system that Maine Department of Inland Fisheries and Wildlife (MDIFW) biologists use to make bear management recommendations. It includes the process for translating data into management decisions (Part I) and techniques for estimating various bear population parameters (Part II). The goal of the current management system was presented in the 1985 bear assessment.

Bear management recommendations are developed annually. Detailed reevaluation of the bear population's size and status, and its relationship to carrying capacity, occurs at 5-year intervals in conjunction with the assessment and planning process. Consequently, the annual management decision making process uses only a portion of the data collected by MDIFW.

This document does not address social, political, or economic considerations related to bear management. Such considerations will be addressed during the next revision of the bear assessment and goals.

REGULATORY AUTHORITY

Current bear management involves changing hunting regulations within limits set by law (Appendix 1). Beginning in 1990, the annual hunting season extends from the Monday preceding September 1 to November 30. Dogs can be used to hunt bears from September 15 to the day preceding the open firearms season on deer. Hunting over bait will be permitted from the Monday preceding September 1 through September 22. Bait sites used to hunt bear must be cleaned up, as defined by state litter laws, by November 10 annually. Bear trapping season begins October 1 and ends October 31. The annual bag limit is one bear per hunter or trapper. MDIFW can shorten or close the seasons in any portion of the state described by recognizable physical boundaries. Current seasons are not the longest permitted (Appendix I), and the Commissioner may increase season length within limits permitted by statute.

MANAGEMENT GOAL AND OBJECTIVES

The bear management goal and objectives were established in 1985 and 1986, through recommendations made to MDIFW by a big game working group representing various public interest groups.

Assumptions

The management goal and objectives are based on the following assumptions from the 1985 bear assessment:

- carrying capacity declined about 10% in all Wildlife Management Units (WMU) through 1990;
- the 1985 bear population was below carrying capacity in all WMU'S;
- the 1985 bear population was increasing; and
- opportunity to harvest bears will be maintained into the 1990's.

Management Goal

Maintain the bear population at 1985 levels (about 21,000) throughout the State's bear range.

Abundance Objective

Maintain pre-hunt bear population densities at 0.8-1.3 bears/sq. mile of habitat in WMU's 2 and 5; at 0.5-0.7 bears/sq. mile of habitat in WMU's 1, 3, 4, and 6; and at 0.2-0.5 bears/sq. mile of habitat in WMU's 7 and 8.

Harvest Objective

Increase annual harvest levels to 1,500-2,500 bears, or to levels needed to stabilize the bear population.

MANAGEMENT DECISION PROCESS

Current management decisions relate primarily to the goal of maintaining a stable bear population near 1985 levels. However, management options are limited. The geographic distribution of harvests can be controlled only through area closures. In addition, expansion of the bear season or bag limit, or allocation limited numbers of bear permits will require legislative action.

The following sections describe the decision process, input criteria used in decision making, and the management options which may result. The management system produces management recommendations annually.

Decision Making

Decision making is a series of **yes** and **no** answers to questions related to the status of the bear population (Figure 1). As the decision-maker responds to the questions on the basis of input criteria, the flow chart guides him to the appropriate management option.

Criteria for Decision Making

Is the bear population on target, stable, increasing or decreasing within each management unit? These questions are answered by applying the following rules of thumb to the criteria described below to evaluate data inputs.

Criteria A

This input answers the question "Is the population on target (at 1985 levels)?". Bear densities on two MDIFW study areas are re-estimated by applying birth and survival rates obtained from research bears on each area to its 1989 (or more recent) density estimate. One of these density estimates is assigned to the bear population in each WMU, based on its habitat classification and perceived harvest level. If the calculations produce a new density estimate for a WMU that is within the range of densities state(f in the abundance objective, the WMU's population is considered to be on target. The population is considered above target if the new density estimate exceeds the designated range, and below target if it falls below the range.

The size of the bear harvest as a gross indicator of trends in bear numbers has limited utility because hunter effort is poorly documented and success rates are unknown. In addition, bears frequently make long foraging trips outside their home ranges during fall months, thus confounding efforts to estimate impact of harvest density on local bear densities.

However, if the statewide harvest exceeds the upper level needed to maintain bear numbers at the target of 21,000-4statewide, the population is considered below target.

Criteria B

The birth and survival rates used in calculating changes in bear densities for Criteria A are also used to calculate population growth rates. Population growth rate estimates from MDIFW study areas are considered representative of the rest of bear range, and are applied to density estimates developed under Criteria A to assess changes in bear numbers on a WMU basis. Density estimates for the current year are compared with density estimates from the 3 preceding years (see Criteria A). If this comparison indicates bear densities in a WMU are changing in the same direction for 2 consecutive years, the WMU's population is considered unstable, and changing at the indicated (average) rate.

In addition, if no more than 40% of radio-collared female bears on a study area were to produce litters per year for 2 consecutive years, the population of that area (and WMU's represented by that area's data) would be considered unstable and declining. If the survival rates calculated for any age class of monitored female bears were to decline below 50% on a study area, the population of the WMU containing that study area would be considered to be declining.

Supporting Criteria

Several additional data collections provide less reliable indicators of the bear population's size and growth. While they are not key components of the decision-making process, they are reviewed as a group to lend support to decisions based on the above criteria.

Animal Damage Control (ADC) records of bear nuisance complaints and nuisance control permits issued by the Warden Service are examined for supplemental evidence of changes in bear numbers. Numbers of bear complaints and control permits can fluctuate widely year-to-year, as they are influenced by a variety of factors unrelated to changes in bear densities. Consequently, short-term changes in numbers of complaints or permits are not reliable indicators of population changes. However, if trends in the incidence of these records are sustained over a 3-year period (as indicated by continued change, totaling >50% increase or decrease compared to the year immediately preceding the period), a change in bear numbers is indicated.

Calculated survival rates for eartagged male bears help to support or refute other data regarding population stability. If the calculated survival rate of eartagged male bears over 1 year of age declines below 50% on a study area, the bear population in WMU(S) represented by that study area is(are) considered unstable.

Beginning in 1990, a bear hunting permit will be required of all individuals hunting bear prior to the opening of the firearms deer season. Although number of permits will not be limited, they will permit MDIFW to begin to track hunting success rates by hunting method and region. If success rates decline with time, the population will be considered unstable and declining. Conversely, increasing success rates will indicate an increasing population. If success rates change in the same direction for 2 consecutive years, with an overall change of >15%, the population will be considered unstable and changing in the direction of success rate change.

Management Options

Recommendations from the current management system can produce one or more of the following management actions:

- reduce length of bear season in parts of the state or statewide;

- reduce (in parts of the state or statewide) the portion of bear season that any of the following methods of take are legal: hunting with bait, hunting with hounds, or trapping;

Under current regulatory authority, MDIFW does not have the ability to extend season length outside of the statutory framework, issue a limited number of bear licenses, increase the bag limit, or restrict certain methods of take. However, other possible management recommendations would be to seek authority from the legislature to institute these management options.

Management Option I

Maintain current season length and open area.

Management Option II

Increase the harvest on a statewide or WMU basis. At present, the statewide harvest can only be increased by season extensions if the current season length is shorter than the maximum permitted by statute.

Alternately, the harvest can be increased on a WMU basis by directing harvest pressure into the WMU through season restrictions or closures in other WMU's (those with bear populations below target and stable or declining, or on target but declining). [NOTE: Adjustments to any WMU's season length will require definition of borders or areas based on physical features. Consequently, borders of the area with altered season length will differ slightly from the WMU's border.]

Management Option III

Reduce harvest in the WMU by, in order of increasing need: 1) decreasing season length; or 2) closing season until the population recovers.

Criteria and Procedures used to Reduce or Increase Harvest

In the event of an over or under-harvest, action to reduce or increase following year(s) harvests would occur under the following criteria and assumptions. The procedure could be applied on a statewide basis, or to any combination of WMU'S. For simplicity, only a statewide over-harvest is described below.

If the harvest exceeds the level needed to maintain the spring statewide population at 21,000 bears, the following year's spring population is expected to decline below the target level. Management action will depend on the severity of the over-harvest.

In cases where the harvest results in a reduction in 2-year mean spring bear numbers below 1985 levels, the following year's season will be shortened to reduce the harvest. The severity of the excessive harvest will determine how large a reduction in season length is needed. Reduction can occur under a wide array of scenarios involving limits on methods and areas hunted. The Commissioner will determine how the season will be shortened, after considering the social issues surrounding the harvesting of bears. The Wildlife Division's recommendations will focus on the amount of harvest reduction required to reverse the population decline. Supporting information, including distribution of harvest between harvest methods and timing of recent harvests will be compiled for the Commissioner's reference when shortening season length to adequately reduce harvest reduction.

The population model (based on research data) will be used to project when spring bear numbers will return to 21,000, and the season may be lengthened when this occurs.

Calculation of Desired Harvest Level

Example: 1991

Assume: A 1990 harvest of 2,000 - 2,300 bears.

1.

Spring 1990 population:	17,325 bears	
1990 Harvest	- 2,000	2,300
1990 non-hunting loss	- 2,250	2,250
Winter 1991 population:	13,075	12,775
1991 cub production	+ 6,135	6,135
Spring 1991 population:	19,210	18,910

*13% of spring population level, based on estimated mean annual extra-legal losses from the population in the mid-80's derived from research and MOTLK data.

2. Therefore, the spring 1991 bear population estimate (18,910 19,210) is 90 - 91% of the target spring population of 21,000 bears, and 109-111% of the spring 1990 population estimate.

3. Calculation of the desired 1991 harvest level begins by:

a) projecting 1992 population size <u>given no harvest occurs in 1991</u>

Spring 1991 population:	19,210	18,910
Non-hunting mortality (1991):	- 2,500	2,450
Estimated cub production (1992):	3,570	3,570
Spring 1992 population w/ no harvest:	20,280	20,030

b) calculating the harvest level which will result in a spring 1992 population equivalent to the spring 1990 level (i.e. prevent further population growth).

Subtract Spring 1990 population est.:	-17,325	17,325
Estimated harvest to prevent pop. growth: ------------------------------------	2,955	2,705

These two parameters are useful for bracketing further discussion of harvest recommendations.

4. Population modeling under two harvest regimes (continued harvesting at about 2,150 bears/year; no harvests) provided population projections for trend analysis. Spring population estimates generated by the model were

averaged as running 2year means, to smooth the annual fluctuation in bear numbers produced by synchronous breeding.

2-year Mean Population Estimate

Harvest Regime	1989-90	1990-91	1991-92	1992-93
2,150 bears/yr during 1991,1992	18,973	18,378	18,739	19,321
No Harvest 1991,1992			19,430	21,878

Therefore, to permit population growth, the harvest should be restricted to <2,700 bears in 1991 and 1992. To ensure continued population expansion toward our 21,000 bear objective, a reasonable harvest objective is to contain the 1991 harvest at the 2,000 2,300 level estimated for 1990.

Discussion of Season Options

Example: 1991

The season options discussed fall under two scenarios: retaining the 1990 season framework with minor alterations, or returning to the season framework of the late 1980's with substantial delay in opening date.

1. Scenario I (1990 Season Regulations)

Assuming a 1991 harvest objective of 2,000-2,300 bears, statistics from 1990 and previous seasons formed a basis for projecting the 1991 harvest, given no season alterations:

Method/Timing	1990 (Estimated)	1991 (Prolected)
Bait/Dogs (weeks 1-5)	1,440	1,200 - 1,600[1,2]
Trapping (weeks 6-9)	50	50
Dogs (weeks 6-9)	150 - 175	150 – 175[2]
Firearms Deer (weeks 10-13)	400 - 650	200 – 300[3]
SEASON	2,040 - 2,315	1,600 - 2,125

Assumptions for the 1991 projection:
[1]Baiting success and effort will combine to produce a 5-week harvest ≤1989 level (1,500 bears).
[2]No change in houndsmen's success or effort from recent years (1989).
[3]Bear harvest during the November Firearms Deer season will be low, following pattern established since 1984.

This harvest projection coincides with the objective harvest range for 1991 (2,000-2,300 bears). Consequently, no change in season dates would be required in 1991.

2. Scenario II (Return to common opening for bait and hounds)

Given a return to a common opening for both baiting and hounds, the 1989 statistics provided a basis for a "guesstimate" of 1991 harvest levels produced by various opening dates. The 1989 rate of kill was assumed to be encountered in 1991, and a mean rate of kill of 51 bears per day was calculated for use in harvest reduction, based on harvest over weeks 2-5 in 1989. This assumption may not adequately account for accelerated harvest rate due to compression of hunting effort into a shorter season.

Delav	Opening Date	Est. Reduction	Est. Harvest
I week	2 September	300 bears	2,400
2 weeks	9 September	600 bears	2,100
3 weeks	16 September	900 bears	1,800
4 weeks	23 September	1,200 bears	1,500
5 weeks	30 September	1,500 bears	1,200

The following table of 1989 kill by week is included for reference while assessing the impact of season options.

Table 1. 1989 Maine bear harvest by week of season and method of kill.

killweek	bait	dogs	trapped	deer	total
1	713	41	3	0	867
2	454	50	14	0	566
3	224	45	10	0	304
4	115	45	11	0	181
5	88	53	4	0	162
6	54	48	7	0	127
7	30	51	4	0	97
8	9	31	0	0	53
9	8	33	2	54	106
10	2	0	0	98	98
11	1	0	0	58	58
12	0	0	0	55	55
13	0	0	0	16	16

Total column may include bears with unknown method of kill.

Assuming the 1991 rate of kill in September is similar to the 1989 harvest, and that a 2,700 bear harvest would occur in 1991 given season dates similar to 1989 (late August opening):

a. A harvest rate of 51 bears/day is used to calculate the number of days to be removed from the season to achieve a harvest of 2,000-2,300 bears. This was the average kill rate for weeks 2-5 of the 1989 season.

2,700 - 2,300 = 400 bears

2,700 - 2,000 = 700 bears

$\frac{\text{400 bears}}{\text{51 bears/day}}$ = 7.8 or 8 hunting days

$\frac{\text{700 bears}}{\text{51 bears/day}}$ = 13.7 or 14 hunting days

b. The season would be shortened by 8 days to reduce the harvest to 2,300 bears, and by 14 days to reduce the harvest to 2,000 bears.

c. To account for the effects of an ever-increasing rate of harvest/day or the impact of compressed hunting effort, the season reductions would be rounded up to the next full-week increments, and a 2-3-week reduction would be recommended for 1991. To achieve a harvest of near 2,000 bears, the opening date would be delayed by 3 weeks, through the Coinmissioner's rule-making authority.

CHRONOLOGY OF BEAR MANAGEMENT ACTIVITIES

By law, the bear season dates and area with an open season must be finalized and made public prior to February 1st of any year. Therefore, it is necessary to make season recommendations, hold public hearings, and set the next season dates before results of the previous season can be completely analyzed (Table 1). If necessary, a public hearing to establish regulations for the next year's bear season would be held prior to mid January.

Bear management recommendations are developed at 5-year intervals, because much of the information used in the decision making process is only meaningful when analyzed over several years. The 2-year reproductive cycle of female bears and annual variation in fall food production can produce year-to-year fluctuations in cub production. Consequently, trends in birth rates only become apparent when 4+ years of data are pooled.

Present information on bear survival comes from small annual samples of radio-collared females and eartagged males. Pooling 4+ years of data on survival produces estimates with smaller confidence limits.

Forest inventory data used in assessing carrying capacity is only collected at 5-year intervals as well. Consequently, the annual decision making process uses broad rules of thumb to establish the criteria used in answering questions about the size and stability of the bear population.

Table 1. Bear season schedule.

	Start	Finish
Department Regulation Proposal		November
Rule Making:		
Regulation to sect. of State		November
Regulation Advertised		December
Public Hearing		January
Advisory Council Meeting		January
Regulation Adopted		prior to February 1
Registration:		
Books Ordered		May
Tags Ordered		May
Stations Established		May
Tagging Material Issued		May
Season (Framework)	Monday preceding Sept. 1 - Nov. 30	

PART II. – BLACK BEAR MANAGEMENT DATABSE

BEAR DATA COLLECTION SUMMARY

Bear Harvest Data

Registration Data

Every legally harvested bear must be registered at a big-game registration station (Appendix II), where a metal seal is affixed to it and information on the bear's sex and age, location of kill, hunter, and hunting method are recorded in registration booklets (Appendix III). These booklets are inspected periodically by District Wardens, and delivered by Warden Lieutenants to the Data Entry Section of the Bureau of Resource Management soon after the close of the bear season (mid-December).

Harvest data are coded and entered into a data base on the IBM Mainframe of the Bureau of Data Processing during the winter months (Appendix IV). Data entry is usually completed by early February. This information is then transferred electronically to the University of Maine's (UM) computer system (Appendix V), and a copy of the registration data is filed on the Furbearer-Bear Project's Personal Computer (PC) in the Bangor Research Headquarters.

Registration data are edited, analyzed, and summarized on the UM system by Furbearer-Bear Project (FBP) personnel using a series of computer programs (Appendix VI). Analyses include review of the geographical distribution of the harvest, its sex and age distribution, chronological distribution, and distribution by method of take (Appendix XVI). This process is usually completed by late March, when a short summary report and a map of the harvest by township are made available to MDIFW personnel and the public.

Beginning in 1990, a mail survey of hunters purchasing bear permits will be completed annually. This sampling will provide information on hunting effort and success rate by hunting method, geographical area, and time of season. Each year's results will be compared to previous seasons' data for trends in success, providing an index to population stability.

Bear Population Data

Research Studies

FBP personnel visit dens of radio-collared research bears in 3 study areas (Appendix VII) during January, February, and March (Appendix VIII). Condition of these bears and their offspring, and characteristics of their den sites, are recorded and coded by FBP personnel (Appendix VIII) This information is entered into the IBM Mainframe by the Data Entry Section (Appendix IV), and then transferred electronically to a data base in the FBP's PC at the Bangor Research Headquarters during April (Appendix IX).

Bears are live-trapped in the Bradford Study Area from May through July to augment the existing sample of radio-collared female bears (Appendix VIII). Resulting capture data are coded by FBP personnel and submitted to the Data Entry Section for entry into the IBM Mainframe in September.

Throughout the year, radio-collared bears are located using light aircraft. Each bear is located about twice a month from April-November, and an additional 2-3 times during the winter denning period. Habitat, activity, and locational data are recorded by pilots flying under contract with the Department (Appendix XI), and then coded by FBP personnel. Approximately twice each year, capture and relocation data are entered into the IBM Mainframe by the Data Entry Section (Appendix IV), and then transferred to the FBP's PC where they are proofed by FBP personnel (Appendices VIII, IX).

Eartags from research bears killed during the hunting season, at damage or nuisance sites, by vehicles, or by other causes are reported to the FBP by MDIFW personnel and by the public in written or oral form. Eartags from most hunter-harvested bears are shipped to Augusta in special eartag envelopes provided with the registration materials, but some tags are reported only in the margins of the registration booklets. Once such reports are received by the FBP, a death certificate form is completed (Appendix VIII), and the information is coded and shipped to the Data Processing Section in Augusta where it is entered into a data management system (Appendix IV). These data are usually entered on an annual basis, and are transferred electronically to the FBP PC in Bangor, where they are proofed and entered into a database (Appendices VIII, IX).

Estimates of densities, recruitment rates, and mortality rates of bears living on MDIFW study areas are developed from tagging and telemetry data, and are used as input for a crude life equation model. The density estimates and model are used to evaluate changes in bear numbers in each of the 8 Wildlife Management Units (WNU) through extrapolation of bear density estimates from MDIFW study areas.

Bear-Man Conflicts

Nuisance Complaints and Control Permits

Records of bear nuisance complaints (Appendix XI) and nuisance control permits (which allow the killing of bears)(Appendix XII) are maintained by the Warden Service.

These records are completed by District Wardens and submitted to Augusta through their respective Division offices on a weekly basis. Historical summaries of nuisance complaints exist, but this information has not been computerized since 1985. Nuisance complaint levels and control permit records are reviewed occasionally for trends in the number of incidents and changes in the geographical distribution of bear-man conflicts (Appendix XVII).

Warden Service complaint records are reviewed by Wildlife Division staff in Augusta on an annual basis, and records which indicate the death of bears are computerized. This information is shipped to the Furbearer-Bear Project Leader for summarization.

Standard summaries of these data include a series of tables which document **some** mortality other than legal kill (MOTLK)(Appendix XIII). However, observations of natural mortalities are usually lacking from these records. Consequently, they are used only as an indicator of gross changes in bear numbers, and MOTLK is estimated from MDIFW research studies.

Habitat Evaluation

Five-year Evaluation

Habitat conditions are reevaluated at 5-year intervals, as part of the planning update (Appendix XV).

LIST OF APPENDICES

BLACK BEAR MANAGEMENT SYSTEM

APPENDICES

Available Upon Request

Trapping and Marking Terrestrial Mammals for Research: Integrating Ethics, Performance Criteria, Techniques, and Common Sense

Roger A. Powell and Gilbert Proulx

Abstract

We propose that researchers integrate ethics, performance criteria, techniques, and common sense when developing research trapping programs and in which members of institutional animal care and use committees address these topics when evaluating research protocols. To ask questions about ethics is in the best tradition of science, and researchers must be familiar with codes of ethics and guidelines for research published by professional societies. Researchers should always work to improve research methods and to decrease the effects on research animals, if for no other reason than to minimize the chances that the methods influence the animals' behavior in ways that affect research results. Traps used in research should meet performance criteria that address state-of-the-art trapping technology and that optimize animal welfare conditions within the context of the research. The proposal includes the following criteria for traps used in research: As Criterion I, killing-traps should render $\geq$ 70% of animals caught irreversibly unconscious in $\leq$ 3 min (calculated with 95% confidence). As Criterion II, live-traps should trap $\geq$ 70% of animals with $\leq$ 50 points scored for physical injury (calculated with 95% confidence). The types of traps described include killing-traps (snap traps, rotating jaw traps, snares, pitfalls, and drowning sets), common sets, and the common types of live-traps (box and cage traps, pitfalls, foothold traps, snares, corrals and nets, and dart collars). Also described are trapping methods for specific mammals, according to which traps fulfill Criteria I and II for which species, and techniques for short-term, long-term, and permanent marking of mammals.

Key Words: killing-traps; live-traps; mammal; marks; research design; traps

Guiding Concepts

Good research on free-living wild animals increases our knowledge of animals and helps wildlife professionals to develop effective conservation and management programs. To be consistent with these ends, research must use sound design to test hypotheses and to answer specific questions while making certain that the research does not have negative effects on the animals that influence research results. Much research on wild mammals requires trapping and marking of animals. We present here recommendations for trapping and marking mammals in research designed to gain scientifically sound information and designed to minimize unwanted, negative impacts on the individual mammals and populations being studied.

Our approach integrates ethics (professional values and conduct), performance criteria, techniques (traps, marks, and methods) and common sense (sound practical judgment). We propose that researchers address these topics when developing trapping programs and when submitting research plans to institutional animal care and use committees (IACUCs[1]). We also propose that IACUCs address these topics when evaluating research protocols. We identify performance criteria for traps, with the caveat that when no available trap meets the recommended criteria and the research is sound, researchers should use traps that best meet research and ethical concerns. The major types of traps and sets for the capture of mammals are discussed below. We present first an overview of traps, which is best done by grouping similar traps. We then present the best methods of trapping different mammals, which is best done by grouping similar species. This approach results in some redundancy but minimizes confusion because some mammals can be trapped using very different traps, similar traps can be used to trap very different mammals, and traps that meet performance criteria for one species may not for other. In the end, our two lists are, perforce, incomplete because responsible researchers strive continuously to improve traps to work more efficiently, more selectively, and more safely for both animals and people.

Ethics

Many philosophers have argued that ethics must be an essential component of how humans treat animals (e.g., Regan 1983; Singer 1975). Since the early 1990s, many biologists have argued forcefully that treatment of animals in research must meet ethical standards and that field biologists must

Roger A Powell, Ph.D., is a Professor in the Department of Zoology, North Carolina State University, Raleigh, North Carolina. Gilbert Proulx, Ph.D., is Director of Science at Alpha Wildlife Research and Management Ltd., Sherwood Park, Alberta, Canada.

[1]Abbreviations used in this article: IACUC, institutional animal care and use committee; PIT, passive integrated transponder.

address some sticky questions (e.g., ASM/ACUC 1998; Bekoff 2000a,b, 2001, 2002; Bekoff and Jamieson 1996; Berger 1998; Berger et al. 2001; Cuthill 1991; Elwood 1991). Bekoff (2002) noted that to ask questions about ethics is in the best tradition of science. Researchers must always work to improve research methods and to decrease the effects on research animals if for no other reason than to minimize the chances that research methods affect the animals' behavior in ways that ultimately influence research results.

All researchers should be familiar with the codes of ethics and the guidelines for research published by professional societies devoted to research on animals. The American Society of Mammalogists (ASM/ACUC 1998) and the Association for the Study of Animal Behaviour and the Animal Behavior Society (ASAB/ABS 2000), for example, outline research methods that these societies find ethically appropriate. These society guidelines are updated appropriately and are intended not to obstruct research but instead, to establish a context for the continued quest to improve research design (ASM/ACUC 1998). All researchers should also be familiar with laws and national standards that affect their research, such as (but not limited to) the Animal Welfare Act and the Endangered Species Act in the United States, The Animals (Scientific Procedures) Act in the United Kingdom, and the *Guide to Care and Use of Experimental Animals in Canada* (CCAC 1984, 1993). Some societies (e.g., ASAB/ABS 2000) base decisions to publish submitted manuscripts in part on whether the research is consistent with the societies' codes of ethics.

Research design should minimize potential long-term effects of trapping (Seddon et al. 1999) and deal with nonrandom sampling (Banci and Proulx 1999). For example, because adult males, dominant individuals, and juveniles are usually trapped first, research using killing-traps can affect population structure of the remaining animals in a nonrandom way. Bekoff argued that researchers should approach research with the basic principles used in everyday life: "Do no intentional harm, respect all life, treat all individuals with compassion, and step lightly into the lives of other beings, bodies of water, air, and landscapes" (Bekoff 2002, p. 23). He challenged researchers to consider such questions as "What happens in *both* locations when individuals are moved from one place to another?" When animals are moved, what is the effect on the remaining members of their species, what are the effects on the social organization of that species, and what are the effects on the integrity of the community? Research should be designed, as practicable and without affecting research goals, to minimize effects on all levels from the individual animals trapped, through social groups and populations, and to communities. Researchers have repeatedly noted that if trapping must continue to be a tool for research and wildlife management, trap technology and management programs must evolve with public sentiments and conservation objectives (Proulx and Barrett 1994; Schmidt and Bruner 1981).

Absolutely minimizing the effects of research and trapping on animals may conflict with research logistics or may cause research costs to exceed available funding. No simple guidelines exist regarding how to weigh the effects of research (positive and negative) on individuals versus groups versus populations versus communities. Likewise, no guidelines exist about how to weigh research funding versus effects on animals (injury) versus importance of results (e.g., for individual animals, animal populations, and humans; however, see also the discussion by Bekoff and Jamieson 1996). Most often, research results have long-term positive effects on populations, and hence to individuals in the future, whereas the individual animals studied and their social groups receive the brunt of negative effects.

Negative effects on animal subjects of field research must, however, be considered in context. Humans are now all pervading. To assume that humans will have no effects on animals if research is not done (thus eliminating negative effects on animal subjects of field research) is just as unethical as ignoring the negative effects of research on animals when research is done. Researchers must be able to argue convincingly that the potential positive effects of their research exceed the potential negative effects.

Criteria for Trap Performance

How animals are trapped and the impact of trapping on mammal populations are major societal concerns (Proulx and Barrett 1989). Traps used in research should meet performance criteria that address state-of-the-art trapping technology and that optimize animal welfare conditions within the context of the research. In most cases, minimal impact of trapping on research subjects leads to minimal aberrant impact of trapping on research results.

Setting performance criteria for killing-traps is arguably easier than setting performance criteria for restraining traps because unconsciousness and death are relatively easy to define objectively, compared with the injury, anxiety, and hardship that may be experienced by restrained animals. The Canadian General Standard Board (CGSB 1984) adopted the criterion that a humane killing trap must render an animal unconscious and unable to recover within 3 min. To some ethicists, 3 min is unduly long, yet it is a realistic time that pushes current technology. When it can be reduced, it will be. Proulx and Barrett (1994) proposed the following criterion for adoption:

> Criterion I - for Killing-Traps: State-of-the-art killing-traps should, with 95% confidence, render ≥ 70% of animals caught irreversibly unconscious in ≤ 3 min.

Despite solid technical advances in trap research and development that meet this criterion (Proulx 1999a), recently developed standards (CGSB 1996; ECGCGRF 1997) have not completely incorporated those technical advances (Table 1). The United States has not signed a binding international agreement to adhere to standards of humane

Table 1 Comparison of trapping standards based on successful state-of-the-art trap research and development (Proulx 1999a) with those of the Canadian General Standards Board (1996) and the European Community et al. (1997)[a]

	Standards				
		Canadian General Board (1996)[c]			
Criterion	State-of-the-art (Proulx 1999a)[b]	AA	A	B	European Community et al. (1997)[d]
Killing-traps					
Minimum performance					
One-tailed binomial test[e]	70%	58%	49%	41%	58%
Two-tailed binomial test	66-100%	51.6-97.9%	42.8-94.5%	34.9-90.1%	51.6-97.9%
Confidence level	95%		None stipulated		None stipulated
Time limit to loss of consciousness/sensitivity					
Squirrel, Ermine	1 min	All: 1 min	All: 3 min	All: 5 min	Squirrel, Ermine: 45 sec
Marten, Mink, Fisher, Lynx	2 min				Marten, Mink: 2 min
All others	3 min				All others: 5 min
Restraining Traps					
Minimum performance					
One-tailed binomial test	70%				62%
Two-tailed binomial test	66-100%		None stipulated		56-91%
Confidence level	95%		None stipulated		None stipulated
Time limit	24 hr		None stipulated		None stipulated
Injury scoring system	Total injury <50 points		None		None

[a]See text for all references.
[b]With killing-traps, 9 of 9 animals (or 13 of 14, etc.) should lose their consciousness within 3 min; with restraining traps, 9 of 9 should be held for 24 hr without serious injuries (total points < 50). Traps that meet these criteria may be expected, at a 95% confidence level, to render ≥70% of target animals irreversibly unconscious, or to hold ≥70% of target animals without serious injuries, within a specific period of time.
[c]Killing-traps only—at least 10 of 12 animals should lose their sensitivity in ≤60 sec in category AA; 9 of 12 animals should lose their sensitivity in ≤3 min in category A; and 8 of 12 should lose their sensitivity in ≤5 min in category B.
[d]With killing-traps, at least 10 of 12 should be unconscious and insensitive within a specific time limit; with restraining traps, at least 16 of 20 animals do not suffer injuries recognized as indicators of poor welfare (injury types similar to those described by Proulx 1999a).
[e]Proulx et al. (1993b) used a one-tailed test to minimize the number of experimental animals.

trapping; it will, instead, develop its own best management practices on the basis of technical, economical, and social criteria (IAFWA 1997).

Proulx and Barrett's (1994) criterion for performance of killing-traps has been used successfully in programs of trap research and development. To date it is the best defined, objective, and published criterion consistent with state-of-the art technological development. Some available traps meet this criterion for use with many mammals (Proulx 1999a).

Much, if not most, research on wild mammals that involves trapping uses live-, or restraining, traps. Tullar (1984), Olsen et al. (1986), and others (summarized by Proulx 1999a) developed systems to score injuries caused by live-traps. Olsen and colleagues proposed scoring each bruise, minor cut, and joint damage between 5 and 50 points, depending on severity; scoring serious damage >50 points, increasing with increased severity; and scoring severe damage >125 points. They set a threshold at a total of 50 points. Mammals, however, respond to capture both behaviorally and physiologically (Kreeger et al. 1990; Proulx et al. 1993a; Seddon et al. 1999; Warburton et al. 1999). To date, no objective scoring system for live-traps integrates physical injuries with behavioral and physiological responses (Proulx 1999a), at least in part because interpreting such responses is not straightforward (Dawkins 1998). For live-traps, we adopt a criterion parallel with that for killing-traps:

> Criterion II - for Live-traps: State-of-the-art live-traps should, with 95% confidence, trap ≥ 70% of animals with < 50 points scored for physical injury.

When reasonable, researchers should collect data not only on physical injury but also on behavioral and physiological responses (e.g., Seddon et al. 1999; Warburton et al. 1999). In addition, they should be able to argue convincingly that their traps minimize both physical injury and negative behavioral and physiological responses compared with other traps that are also consistent with the research goals and logistics.

For both killing- and live-traps when no available trap meets these criteria, researchers should use traps that approach the criteria best. They also should minimize the number of animals captured if appropriate to research design, and should incorporate research to improve trap design within their research programs. For good research that is well designed and otherwise deserving of IACUC approval, a lack of traps that meet Criteria I or II must not be grounds, in and of itself, for an IACUC to fail to approve a protocol.

Procedures and Methods

Sample Size, or Number of Individuals That Must Be Trapped

Occasionally field research design does not require maximal numbers of animals to be trapped. When this is the case, researchers can often estimate a priori the numbers of animals that must be trapped and choose the research effort needed to test hypotheses, to meet management goals, or to reach objectives for animal control. For most mammal species, or for closely related species, the literature contains information on trapping success and summary statistics for sex ratios and age distributions of animals trapped. Researchers can estimate sample sizes needed for statistical significance and for adequate statistical power using information from the literature, from pilot data, or from both.

True experiments require random assignment of multiple (≥ 2) treatments (one of which might be a control) and replication (Ratti and Garton 1994). Not all research requires experiments, but nearly all research requires appropriate replication. If research questions relate solely to individual animals, then the unit of measure that must be replicated is individuals. If research questions relate to social groups or to populations, then those units require replication. To replicate individuals in an attempt to answer population-level questions is pseudoreplication (Hurlbert 1984), which can lead to conclusions that are critically misdirected and incorrect. When variation among individuals is limited, however, group and population questions can sometimes be answered with adequate replication of individuals (Still 1982). In other words, variation among individuals can be used to estimate variation among groups or among populations when variation among individuals is low across all groups or populations. Replication of populations is often impossible for large mammals, necessitating the (cautious) use of individual variation to estimate population-level effects. Nonetheless, the validity of inferences from small samples is not straightforward (Hurlbert 1984, Kroodsma 1989, McConway 1992, Searcy 1989) and requires solid support.

Sample size on the correct level (individual, group, or population) can often be minimized in one of the following ways: by designing research that will yield data appropriate for statistical tests needing small samples (the tests may be parametric, nonparametric, or Bayesian); by using factorial design to explore the effects of several variables in one experiment; by using sequential and multivariate statistical methods; or by using repeated measures design (McConway 1992). In the end, for most field research involving trapping, increasing sample size increases statistical rigor, which is urgently needed.

Handling

Handling of trapped individuals should minimize impact on the individuals. Quick handling often, but not always, minimizes impact. In general, but not universally, using anesthesia reduces the stress of being handled. Anesthesia may or may not, for example, reduce capture myopathy in ungulates (Beringer et al. 1999; Kock et al. 1987; Read et al. 2000). Handling mammals without anesthesia sometimes returns animals to their social groups most quickly and allows quick release without danger of predation after handling. Yet, even for those species, such handling may cause abnormal behavior long after release and can reduce recapture success. When anesthesia is used and recovery is not rapid, trapped animals may need food, water, and other resources as well as protection from predation, weather, and other effects until they can be returned to the wild (e.g., Gehring and Swihart 2000; King 1973, 1975).

Before using anesthesia, a researcher should gain experience with administration and monitoring and should consult with a wildlife veterinarian. When small mammals are handled, body and appendages should be restrained while allowing easy breathing (ASM/ACUC 1998). Small mammals can be restrained in cloth, mesh, or heavy plastic bags, and the latter may be used to administer anesthesia if necessary.

Common Sense

Researchers must use common sense about trapping mammals, which implies that a researcher will judge appropriately the methods required for a study. Many research goals that required trapping even in the 1990s can now be achieved without trapping. When appropriate data can be collected more easily and inexpensively without trapping, common sense maintains that trapping should be avoided (Bekoff and Jamieson 1996). Presence/absence data can be collected using track plates, remotely triggered cameras, and hair traps (Zielinski and Kucera 1995). Remotely triggered cameras allow one to identify individual animals that received obvious markings when trapped a first time, which decreases the need for extended trapping. DNA obtained from tissue from hair follicles allows identification (albeit sometimes with unacceptable expense) of each individual that has left hair in hair traps (Woods et al. 1999).

Mammals that can be observed readily can often be identified as individuals using natural markings (Kelly 2001; Mukinya 1976; Pennycuick 1978). Outfitting large mammals with collars bearing remotely discharged, anesthetizing darts reduces necessary retrapping, reduces the capture of nontarget species and individuals, minimizes the probability that target animals will not be recaptured, and reduces the trauma and stress of recapture (Powell et al. 1997; Powell, unpublished data). In addition, data and summary statistics in the literature can sometimes be used with new statistical and modeling techniques to test hypotheses without new field research. Replication of research is central to good science, and replication of important results should never be discouraged. Unnecessary duplication differs from replication, however, and should be avoided. Repeating research that has been replicated many times already, in the absence of significant, new permutations, is considered duplication.

The choice of live- (restraining) versus killing-traps depends, at the least, on research goals, research design, and study site. Both live-capture and kill-trapping can contribute to important research on evolution, ecology, animal behavior, physiology, parasitology, genetics, and other disciplines. Live-traps allow the live release of trapped animals, including nontarget animals. If, for example, pets or members of an endangered species have a reasonable probability of capture, then live-traps are dictated. When nontarget captures are unlikely, holding an animal in a live-trap only to kill it later to collect a sample may be less humane than using a quick-killing trap. Keeping animals alive may be required, however, to avoid freezing or decomposition of tissues to be sampled (Kreeger et al. 1990).

Both live-traps and killing-traps can be monitored remotely; however, doing so may be unreasonably expensive, especially when traps can be checked easily in person multiple times daily. Remotely monitored traps must be visited regularly for maintenance because animals may avoid capture but still disturb trap sites and render the sets ineffective. Remote monitors must be set so that monitor failure causes traps to be checked. The device described by Graf et al. (1992), for example, fails to meet this safety criterion because trapping an animal activates the monitor. If this monitor fails, animals can be trapped and the researcher not be notified.

Killing animals is important for some research on evolution and systematics, for wildlife management, and for animal damage control. Without the continuous collection of new specimens, museum collections cannot document changes in genetics, populations, species, and species' ranges. Mammal specimens should be deposited in museums that meet the standards set by the American Society of Mammalogists (ASM/CSC 1978).

Whether using killing-traps or live-traps, common sense dictates choosing traps that maximize both selectivity and efficiency (Pawlina and Proulx 1999). Selective traps minimize the capture of nontarget species or nontarget individuals within a species, thereby increasing the rate of data collection and reducing the overall impact of the research on the ecological community in the study area. Efficient traps have high capture rates and thereby lead to rapid data collection.

Finally, as practicable for the research, researchers should choose traps that minimize pain and discomfort. Mammals are sentient and have the ability to perceive injurious stimuli (Kitchell and Johnson 1985). A trapping program should avoid discomfort as much as possible if for no other reason than not to do so can lead to negative affects on the animal subjects that ultimately affects the research results.

Traps

Traps used to capture mammals are diverse. They can be divided into several general types, yet tremendous variation exists within types. In this article, we present the major types; note, however, that Proulx (1999a) presented more detailed descriptions of some traps and described some test results. The list herein must be incomplete because responsible researchers are always striving to improve traps. Where traps have been evaluated for general performance, we report the results below. Where performance is specific to individual species, we report the results with information about trapping individual species.

Live-Traps

Capture devices classified as live-traps include box and cage traps; pitfall traps; foot-hold traps; foot-, neck-, and body-snares; and corrals and nets. A brief description of each device appears below.

Box and Cage Traps

Box traps restrain animals inside a box with solid wood or metal walls and tops. The traps with wire or nylon mesh walls are cage traps (some with tops). All box and cage traps work under the same principle: an animal enters the trap through an opening, is usually attracted to bait, and moves a trigger or otherwise causes the door to close and lock. These traps are diverse and range in size from tiny boxes to capture mouse-sized mammals, to huge structures made of road culverts or logs to trap large carnivores, to netted cage traps to capture ungulates.

Box traps are used mostly to capture mammals weighing < 2 kg, although netted cage traps, culverts, and log traps capture large mammals. For researchers to build these latter traps requires considerable time, effort, and expense. Most netted cage traps are variations of Clover's (1954) trap: a pipe frame surrounded with netting (McCullough 1975; VerCauteren et al. 1999). Barrel or culvert traps, made from ≥ 2 oil drums welded together or from sections of highway culvert, are commonly used to capture bears (*Ursus* spp.).

These traps are cumbersome to move and often are mounted on a trailer pulled by a truck. At best, they cannot be set far from roads. Large live-traps (1 × 1 × 2 m) built in situ with logs are also used to capture bears and other carnivores such as wolverines (*Gulo gulo;* Copeland et al. 1995).

Animals captured in box and cage traps appear to undergo less trauma than those captured with limb-holding traps (Powell, unpublished data; White et al. 1991). Although some box traps hold mammals without injury for up to 24 hr (Proulx et al. 1992), others may cause captured mammals to break teeth or to abrade skin on their muzzles (Powell and Proulx unpublished data on red squirrels [*Tamiasciurus hudsonicus*], muskrats [*Ondatra zibethicus*], weasels [*Mustela* spp.], American martens [*Martes americana*], fishers [*Martes pennanti*], and black bears [*Ursus americanus*]). Box traps without insulated nest boxes and bedding are not recommended for small mammals in winter when temperatures are −20°C, or if researchers cannot check traps daily. Traps should be concealed and covered with vegetation to protect animals from sunlight and rain. Enclosures may be constructed to protect small traps from disturbance by predators (Layne 1987). Remote devices can signal when a trap has sprung and allow quick attendance to captured animals, can reduce the accumulation of human scent at trap sites, and can reduce time and effort allocated to trap tending (Arthur 1988). Remote devices must be constructed so that device failure causes traps to be checked.

Hancock and Bailey live-traps for beavers (*Castor canadensis*) resemble wire mesh suitcases that are set open, baited with appropriate food, and spring closed around a beaver that moves a trigger when taking the bait.

Pitfall Traps

A pitfall trap is a container (usually ≥ 40 cm deep and 20 to 40 cm in diameter; Jones et al. 1996), that has smooth vertical walls and is placed in the ground. Pitfalls are effective devices to capture the smallest (< 10 g) terrestrial mammals such as shrews (*Sorex* spp., *Blarina* spp.; Spencer and Pettus 1966). Animals may be attracted to pitfall traps with bait or may fall into traps because they are placed along travel-ways or equipped with drift fences (barriers designed to direct small mammals into traps; Bury and Corn 1987; Handley and Kalko 1993). When set with bait or food, pitfall traps can maintain trapped mammals for several hours. Trapped mammals, however, may be subject to predation by larger mammalian predators and, when multiple shrews fall into the same trap, one often kills and consumes the others. Consequently, pitfall traps must be checked multiple times daily to maximize survival of trapped mammals.

Foothold Traps

Foothold traps have two jaws that open to 180° at set position and clamp together to hold an animal's paw. A trap is attached by a chain or cable to an anchor and restrains a captured animal from moving beyond the radius of the chain. Foothold traps are available in various models (some with padded jaws), with jaw spreads ranging from 7.6 cm for muskrats to 19 cm for wolves (*Canis lupus;* Proulx 1999a). These traps are used most frequently to trap carnivores, although diverse other species have also been targeted (e.g., Australian brushtail possums, *Trichosurus vulpecula;* Warburton et al. 1999). Most steel (unpadded) foothold traps, but not all, fail to meet Criterion II (Proulx 1999a). Skill in choosing trap size and in making and maintaining proper sets greatly affect the impact of a trap on the targeted mammal.

The EGG trap (EGG Trap Co., Ackley, Iowa) has a plastic housing with an interior pull trigger mechanism that causes a bar to prevent an animal from withdrawing its paw from the housing. It works well with mammals that manipulate and explore with their paws.

In the search for modified foothold traps that cause few injuries, Linhart et al. (1991) reported that 71% of coyotes (n = 24) captured in steel foothold traps equipped with tranquilizing tabs (chlordrazepoxide and propiopromazine) sustained little or no visible foot damage. Sahr and Knowlton (2000) also reported minor injuries in wolves caught in traps with propiopromazine. Traps with tranquilizing tabs are not used by commercial trappers. Yet, along with recent developments in central nervous system depressants, the device may be of interest to researchers wishing to reduce further the injuries caused by padded-jaw traps.

Foot-, Neck-, and Body-Snares

A foot-snare holds an animal's paw in a loop of cable that is often tightened initially by a spring. Like foothold traps, foot-snares are usually anchored to restrain captured animals. Some, but not all, meet Criterion II (Onderka et al. 1990, Shivik et al. 2000). Although many different foot-snares are similar in appearance, they do not perform equally. Researchers must be familiar with the literature to select the foot-snares that work best for their animals.

Neck-snares have been used to capture canids (Bjorge and Gunson 1989; Nellis 1968). Noonan (2002) promoted a new device that throws a loop of cable over an animal's head onto its neck. A stop attached to the cable prevents the loop from choking the captured animal, which is held as if restrained with a leash and collar. This device may cause fewer injuries than steel-jawed foothold traps, but it still does not meet Criterion II (Shivik et al. 2000). Nonetheless, neck-snares equipped with diazepam tabs calmed captured coyotes and reduced facial and oral lacerations (Pruss et al. 2002).

McKinstry and Anderson (1998) live-trapped beavers with body-snares instead of using heavy, cumbersome traps. Although entanglement and predation accounted for 5% mortality, the researchers effectively captured beavers around their chests, abdomens, or bases of their tails.

Corrals and Nets

A drive corral usually has nylon netting supported by posts to delineate an enclosure and a funnel fence that directs animals into the corral. Mammals as small as jackrabbits (*Lepus* spp., Henke and Demarais 1990) and as large as ungulates have been restrained in drive corrals. Wolves (Okarma and Jedrzejewski 1997) and ungulates (Beasom et al. 1980) have been captured in nylon drive nets that are stretched loosely between two solid objects and supported by poles or branches. Drop nets can be effective to capture ungulates (Conner et al. 1987); with baits or lures, animals are attracted under a drop net that is mechanically operated from a blind. Cannon nets, also called rocket nets, are large nets propelled over ungulates (Beringer et al. 1999). A hand-held net-gun fired from a helicopter is a highly selective capture technique used for large ungulates (Barrett et al. 1982; Carpenter and Innes 1995).

Drive corrals, nets, and string traps appear to improve efficiency over cage traps for trapping ungulates, but they have not been assessed from an animal welfare perspective. The preliminary data of Okarma and Jedrzejewski (1997) suggest that drive nets cause less injury to wolves than foothold traps.

Mist nests are effective for capturing flying bats (Kuenzi and Morrison 1998). These loose nets, which are used mostly to live-trap birds, are made of thin, black line and are set between vertical poles. They are inexpensive and portable but must be tended constantly; bats become entangled and must be freed individually in a timely fashion (Jones et al. 1996). The Hart trap, which has a large rectangular frame crossed by a series of vertical wires (Constantine 1958; Tidemann and Loughland 1993; Tidemann and Woodside 1978), has an advantage over mist nets because it eliminates the tedious task of extracting each bat separately (Jones et al. 1996). When a bat hits the bank of wires, it usually falls into a bag beneath the trap, from which it can be removed easily.

Dart Collars

Transponder radio collars with remotely triggered darts containing anesthetizing drugs cause less physical trauma and less stress than restraining traps (Powell, unpublished data). Because the animals are not restrained, however, the possibility exists (usually small) that the drug may take effect when an animal is in water, near a steep slope, or otherwise in a place that can result in serious injury when the animal falls.

Killing-Traps

Capture devices classified as killing-traps include snap and planar traps, rotating-jaw traps, killing box traps, killing-snares, pitfalls, and submarine traps. A brief description of each device appears below.

Snap and Planar Traps

Mousetraps and rat traps, often called snap traps, have one jaw (often "U"-shaped but sometimes a straight bar) that closes from 180° on a flat surface to strike an animal. In planar traps, the spring forms the killing bar. These traps range in size, and various models have been used for killing small mammals to medium-sized carnivores such as American martens (Proulx 1999a,b). Trap placement is critical, both to minimize the chances of trapping nontarget animals that are too large to be killed quickly by the snap trap used and to maximize the chances that an animal approaches a trap so that the jaw can give a killing blow. Despite being used "forever" and having killed uncountable numbers of small mammals (and birds), effectiveness has been quantified for only a very few snap traps (Proulx 1999a,b). Of these, the Bionic trap (W. Gabry, Vavenby, British Columbia, and A. Gabry, Camrose, Alberta), a large mousetrap powered by a coil spring, appears to be the most versatile trap to meet Criterion I, and it has been found effective for the capture of weasels (Proulx unpublished data), minks (*Mustela vison*), martens, and fishers (Proulx 1999a).

The Fenn trap, developed in Britain during the 1950s, is a large snap trap used to capture small mustelids. It may be judged more humane than foothold traps because fewer animals are found alive or seriously injured (King 1975). Nevertheless, on the basis of limited field observations and on laboratory mechanical evaluations (Proulx unpublished data; Von Eerdenburg 1988), Fenn traps (and similar models) appear not to meet Criterion I (Fenn traps, FHT Works, High Street, Astwood Bank, Redditch, Worchestershire, England).

One planar trap, the Kania 2000 trap (Kania Industries Ltd., Nanaimo, British Columbia), is appropriate for mammals that are the size of American martens; it met Criterion I in laboratory tests but had equivocal results in the field (Proulx 1999a). The trap was being sold in Europe in 2002 for the capture of Norway rats (*Rattus norvegicus*) and gray squirrels (*Sciurus carolinensis*) (C. Kania, Kania Industries Ltd., Nanaimo, British Columbia, personal communication, 2003).

Rotating-Jaw Traps

A rotating-jaw trap has two metal frames, usually square or rectangular and hinged at the centers of two opposite sides, which allow a torsion spring on each side to rotate the frames and close them in a scissor-like fashion. Rotating-jaw traps, although called back-breaking traps, do not always kill animals quickly and sometimes act more like holding devices (Novak 1981). Proulx's (1999a) review of the most popular models noted that standard rotating-jaw traps do not meet Criterion I. By welding clamping bars on the striking jaws (to increase clamping force), using stronger springs (to increase striking force), and using triggers that position animals properly for blows in vital regions, rotating-jaw traps can meet Criterion I. Researchers must select rotating-jaw traps carefully. Many models available on the market bear similar names but do not all meet Criterion I (Table 2).

Killing Box Traps

Killing box traps have a striking jaw set within a box or pipe (i.e., the traps are driven by a spring to strike an animal ventrally when the trigger is released). These traps are used in North America mostly to kill pocket gophers (*Thomomys* spp.). Most have not been tested for effectiveness, but two commercially available traps did fail to meet Criterion I and one experimental design did meet the criterion (Proulx 1999c).

Killing-Snares

Manual snares are wire nooses set on land or under water; an animal captured provides the energy to tighten the noose around its own neck. Tests of manual snares with several target species of terrestrial mammals and with beavers failed to meet Criterion I (Proulx 1999a). Power snares, wherein one or more springs provide the energy necessary to tighten the noose, are commercially available to kill large carnivores but require further development to meet Criterion I. Proulx and Barrett (1990) showed that some models have the potential to render neck-captured red foxes (*Vulpes vulpes*) unconscious in ≤ 6 min.

Pitfall Traps

Pitfall traps with water in the bottom are often used to capture and to drown shrews and other small mammals. Specimens are not damaged by capture, multiple captures are possible, and traps do not require frequent monitoring. Drowning of some small mammals (e.g., meadow voles, *Microtus pennsylvanicus*), however, does not occur consistently within 3 min (Proulx 1999a). In addition, killing trapped animals by drowning raises ethical issues because drowning animals often die slowly with hypoxia-induced discomfort and distress (e.g., Bluett 2001; Ludders et al. 1999).

Traps Used in Drowning Sets

Submarine traps (box traps set under water, or rotating-jaw or foothold traps set on surface and sliding under water when fired) are used traditionally to capture beavers, muskrats, minks, and otters (*Lontra canadensis*). Because captured animals struggle for more than 3 min (Proulx 1999a), these traps do not meet Criterion I, and the traps raise ethical concerns related to drowning.

Sets

All traps can be set in diverse ways. Researchers consistently adapt their sets to increase trapping efficiency and selectivity and to increase trap effectiveness. Proper sets can sometimes make the difference between a trap meeting and not meeting Criterion I or II. When opting for a particular trap set, researchers must consider (1) trap elements, (2) trap location, and (3) baited versus trail sets.

Trap Elements

For traps to be most effective and selective, the tripping force of the trigger must match the size of the target ani-

Table 2 Characteristics of rotating-jaw trap models and their ability to kill mammals (after Barrett et al. 1989; Fur Institute of Canada 1994; Gilbert 1992; Novak 1981; Proulx 1990; Proulx and Barrett 1993a,b; Proulx and Drescher 1994; Proulx et al. 1990, 1995b; Sabean and Mills 1994)[a,b]

Trap model	Mean momentum (kg/m/sec)	Range of clamping forces (N)	Species	Humaneness*
C120 Magnum	1.09	254-473	American marten, mink	Yes
C330 with clamping bars	3.27	271-607	Lynx, beavers	Yes
Conibear 330	2.65	0-252	Lynx, raccoon, beaver	No
Conibear 160	?	?	American marten, raccoon	No
Conibear 220	1.45	206-472	Fisher, raccoon	No
Conibear 280	2.03	0-364	Raccoon	No
Conibear 120	0.54	0-224	American marten	No
Sauvageau 2001-5	0.81	310-430	American marten	No
Sauvageau 2001-8	2.10	446-585	Raccoon	No
			Arctic fox	Yes

[a]See text for all references.
[b]Sabean B, Mills J. 1994. Raccoon: 6" × 6" body-gripping trap study., Unpublished 3-page report prepared by the Nova Scotia Department of Natural Resources in 1994.
*At a 95% confidence, ability to render ≥70% of animals unconscious in <3 min.

mals. A trap with a heavy tripping weight cannot trap small target animals effectively, and a trap with a light tripping force may not be selective enough (e.g., Phillips and Gruver 1996; Smith et al. 1971). Trigger characteristics (e.g., shape and size) may discourage an animal from entering a trap. For example, while Barrett et al. (1989) showed that C120 Magnum (Les Pièges du Québec Enr., St. Hyacinthe, Québec) traps captured and killed martens effectively and met Criterion II, Naylor and Novak (1994) reported poor capture success. The latter had equipped their traps with four-prong triggers that discouraged animals from entering the traps.

All of the elements of a trap must be taken into consideration when setting it. For example, Mowat et al. (1994) found that foot-snares attached loosely to trees or drag poles led to major injuries that could cause the death of the animals in nearly 30% of all captures. In contrast, traps properly set to eliminate tangling of the snare in brush caused major injuries in only 3% of captures. In culvert traps, ventilation holes of the wrong size lead bears to break teeth. If traps are not elevated and outfitted with sufficient drain holes, trapped bears stew in their own urine and feces.

Trap Location

No matter how humane a trap might be, placing it in an improper location can lead to unacceptable capture results. For example, culvert traps made from black oil drums can be effective bear traps but they become solar ovens in direct sunlight. Raccoons (*Procyon lotor*) captured in EGG traps along water courses (Hubert et al. 1996) may not sustain injuries but may suffer or even die from hypothermia if they are held standing in cold, shallow water.

The position of a trap in a set has a major impact on success of capture and injuries sustained by captured animals. For example, when trapping lynxes (*Lynx canadensis*) with a killing, rotating-jaw trap, Proulx et al. (1995b) placed the trap at least 23 cm above ground with its center in line with the bait attached at the back of a cubby (logs piled in a funnel shape to direct target animals to the bait and trap). When traps were set too low, lynxes tried unsuccessfully to go over the trap or lost interest in the bait. When traps were too high, lynxes used their paws to reach the bait and inadvertently fired the trap, thus becoming restrained by their paws instead of being killed by blows to their necks.

Bait Versus Trail Sets

A baited set uses food or scent to draw target animals to the trap, whereas a trail, or blind, set is placed where a target animal is expected to travel on its own. Baited traps have higher capture rates than trail sets, particularly in carnivores, but attract nontarget as well as target animals. Capturing nontarget animals may therefore lower the efficiency of baited traps. Trail sets may be highly efficient and selective for capturing animals that establish trails (e.g., muskrats, hares [*Lepus* spp.], bears, and deer [Cervidae]).

Trapping Methods for Specific Mammals

Small Mammals

Small mammals are herbivorous or insectivorous mammals generally weighing $\leq$ 300 g (i.e., the size of a squirrel or smaller). Some researchers have considered rabbits and hares to be small mammals (ca. 1 kg), while others have considered squirrels not to be. The category generally includes, but is not limited to, small rodents, small lagomorphs, insectivores, bats (sometimes), and small marsupials.

For most research, these mammals are best live-trapped using box or cage traps (e.g., Bondrup-Nielsen 1987; Getz et al. 2001; Gilbert and Krebs 1991; Millar and Innes 1983; Peacock and Smith 1997; Steele and Powell 1999; Stratham and Harden 1982; Wolff and Cicirello 1991) or pitfalls for shrews (e.g., Spencer and Pettus 1966). Because of their high metabolic rates, these mammals (especially shrews) cannot remain in live-traps a long time without food, therefore bait must be of an adequate amount to last between trap checks and must nourish the target animals appropriately. During winter, bedding in live-traps can reduce mortalities; raw wool with natural lanolin makes excellent, warm, dry bedding because it is an excellent insulator that repels water. Live-traps for small mammals usually need to be checked at least twice a day, and more often for shrews or when weather is extremely hot, cold, or wet. Sometimes making live-traps inoperative during the heat of the day is best. Checking traps at night may be warranted but only when animals can be handled safely and effectively. Traps must be set to protect captured animals from flooding and sometimes from harassment by predators.

When research design requires mammals to be killed, snap traps are generally used (Batzli et al. 1983; Krefting and Ahlgren 1974; Powell and Brooks 1981). Because most of these traps have not been tested against Criterion I, care should be taken to use traps that will kill target animals quickly, to use sets that encourage target mammals to approach from a direction that makes the traps most effective, and to use sets that discourage nontarget animals.

Trap design should be appropriate to the target mammals and to the goals of the research. Points to consider include trap material (e.g., wooden live-traps provide extra insulation but are bulky; collapsible, sheet metal traps can be carried far into back country but are not as sturdy as noncollapsible traps), construction (e.g., whether it allows multiple captures), and habits of target mammals. Different trap designs and constructions, for example, have different trapping efficiencies for different small mammal species, mammals of different mass, and, possibly, different study sites (Boonstra and Rodd 1982; Slade et al. 1993).

Traps should be spaced appropriately to answer the research questions and appropriately for the biology of the mammals being studied. Traps might be spaced so that each individual has one trap within its home range (to trap as many different individuals as possible) or so that each individual has many traps in its home range (to recapture each individual many times and delineate its home range). Traps are commonly set along transects or on grids (Sullivan 1997). Traps should be placed at habitat features (e.g., in coarse woody debris, by trees, along runways, or by burrows) when possible to maximize capture success. Setting two or more traps at every station reduces saturation of traps with "trap-happy" individuals (live-traps) or with individuals that are readily captured (killing-traps; Drickamer 1987). Trap numbers and placement are ultimately a balance of research design and the number of traps that can be tended feasibly (Bowman et al. 2001).

Pitfall traps must be deep enough to prevent escape of target mammals. They should be placed to minimize capture of nontarget animals and to minimize loss to predators. For some species, guide fences (natural objects or constructed) increase capture efficiency. Pitfall traps are also often set along transects or on grids. To trap fossorial mammals, traps must be set in their burrow systems, which are often identified by clusters of relatively fresh mounds (Witmer et al. 1999).

Mist nests and Hart traps for bats must be tended constantly to prevent bats from becoming inextricably entangled, to prevent them from chewing the net, to prevent escape, and to free the bats in a timely fashion (Jones et al. 1996; Kuenzi and Morrison 1998). Weather conditions, habitat, moonlight, roosting habits of the target bat species, daily and nightly activity patterns, seasonal movements, and colony size all can influence capture success and should be considered in capture protocols (Jones et al. 1996).

Medium-sized Herbivores

Medium-sized herbivorous mammals generally weigh between 300 g and 35 kg. The category includes a diversity of rodents, lagomorphs and marsupials. They are commonly captured in box or cage traps (Grisemer et al. 1999; Proulx and Gilbert 1983; Sullivan 1997).

Hancock and Bailey live-traps for beavers are bulky and usually set in shallow water (Hodgdon 1978; Taber and Cowan 1969). The traps can be difficult to set, and care must be taken to prevent a trapped beaver from rolling its trap into deep water and drowning. McKinstry and Anderson (1998) used body-snares to live-trap beavers. Trap mortality with body-snares, due to predation and entanglement of animals, was slightly higher than those reported for traps.

Henke and Demarais (1990) used a drive corral to capture black-tailed jackrabbits (*Lepus californicus*). With help from assistants, Henke and Demarais drove jackrabbits toward a funnel of fencing that led to a 4.6 × 3.7 m corral. A gill net inside the corral improved safety and handling efficiency. They judged the drive corral to be safer and to provide easier handling than cage traps, which are most often used for rabbits and hares.

Medium-sized marsupials are often trapped using cage traps (e.g., Fisher and Lara 1999). Warburton et al. (1999) trapped Australian brushtail possums using padded and unpadded foothold traps and cage traps. Possums captured in unpadded foothold traps experienced the greatest physical injury, whereas possums captured in cage traps showed the mildest physiological and behavioral responses. Warburton and colleagues did not report relative capture efficiencies.

A variety of killing-traps are available for medium-sized herbivores because many of these mammals are trapped for fur or meat. Rotating-jaw traps and drowning foothold sets are commonly used to trap semiaquatic mammals (Gilbert 1992; Parker 1983). Although they do not meet Criterion I, manual neck-snares are used to capture snowshoe hares (Proulx et al. 1994).

Although traps for medium-sized herbivores are sometimes set along transects or grids (Sullivan 1997), trapping is usually most productive when traps are set at specific habitat features such as feeding stations, defecation posts, beaver dams, runways close to active houses and burrow systems, and trails (Griesemer et al. 1999; Proulx 1981; Proulx and Gilbert 1983). Baker and Clarke (1988) live-trapped nutrias, or coypus (*Myocastor coypus*), on baited rafts.

Many animals use runways in common with snowshoe hares (Keith and Meslow 1966). In Newfoundland, snaring for hares has affected the endangered American marten population significantly, and snares must be modified to capture hares but to allow martens to escape (Proulx et al. 1994).

Large Herbivores

The category of large herbivores includes deer, sheep, and goats (Capridae), antelopes (Bovidae), other ungulates, and kangaroos (Macroporidae). These animals are often captured using netted cage traps, rocket or cannon nets, corral traps, or drive nets (Aldous 1958; Beasom et al. 1980; Beringer et al. 1999; Clancy and Croft 1992; Hansen et al. 1980; Spillett and Zobell 1967; VerCauteren et al. 1999).

Animals must be handled quickly, and possibly immobilized once captured, to minimize self-inflicted injuries from struggling and to reduce capture myopathy. Capture myopathy, or capture stress, is a disease primarily of ungulates (but also many other mammals and birds). It is associated with capture and handling, and it results in cardiac and skeletal muscle necrosis (Pond and O'Gara 1994; VanReenen 1980). Collapsible netted cage traps facilitate handling (VerCauteren et al. 1999). Beringer et al. (1999) recommended limiting noise at capture sites, minimizing handling times, and blindfolding animals. Immobilizing deer chemically reduces struggling and physical injuries. Capture myopathy is sometimes related to specific capture methods within studies but not across studies (Beringer et al. 1999; Kock et al. 1987; Read et al. 2000), leading us to believe that details related to capture methods are critical to this disease. Mortality due to predators and accidents may be highest with netted cage traps (Beringer et al. 1999).

Captures with rocket nets and netted traps are most effective at prebaited sites (Beringer et al. 1999, VerCauteren et al. 1999). Trapping devices should be placed in areas that receive high use by animals. Trails between bedding and feeding areas are ideal sites if they are far enough from roads so that neither traps nor animals are visible to the public (VerCauteren et al. 1999). Brown or green netting is less obvious to people (Rongstad and McCabe 1984). To minimize mortality and injury, netted cage traps should be checked at least twice a day or monitored remotely. Because rocket nets are fired when researchers choose, researchers can be more selective than with other traps. Injuries and mortality can be reduced by building corral traps with wooden posts (not metal, nylon, or other cloth netting; and not woven wire; Hansen et al. 1980). Corral traps and drive nets can capture larger numbers of animals at one time.

Moose (*Alces alces*) and other large ungulates have been captured highly selectively using a hand-held net-gun fired from a helicopter (Barrett et al. 1982; Carpenter and Innes 1995). White-tailed deer (*Odocoileus virginianus*) have been recaptured using radio telemetric collars outfitted with darts (Mech et al. 1984).

Small to Medium-sized Carnivores and Omnivores

Small to medium-sized mustelids, procyonids, small felids and canids, herpestids and small vivirrids, and dasyurids and didelphids can all be trapped effectively with box or cage traps baited with food or attractive scents (Arthur 1988; Bluett 1992; Bull et al. 1996; Genovesi and Boitani 1997; Jones 1995; Jones and Barmuta 1998; Powell 1979, 1993; Stratham and Harden 1982; Woolf and Nielsen 2002). Many of these mammals (particularly mustelids) struggle with cage traps, damage teeth and claws, and scrape skin from their muzzles if mesh size is too large (mesh size should be $\leq$ 2.5 cm, and $\leq$ 1 cm for the smallest of these mammals).

If possible, weasels and minks are best trapped in wooden traps, preferably with an attached, insulated nest box. A wooden nest box is also good for American martens, even attached to a cage trap. Fishers usually pull branches and ground debris into cage traps once captured but seldom struggle with the wire mesh until approached by a human; thereafter, struggle with the wire mesh may be vigorous and can lead to significant, self-inflicted injury (Powell, unpublished data). Raccoons and oppossums (*Didelphis virginiana*) can be captured in box traps and EGG traps with little to no injury (Hubert et al. 1996 1999; Proulx et al. 1993b). Raccoons should not be captured in conventional foothold traps because they may mutilate themselves once captured (Hubert et al. 1996; Proulx et al. 1993b).

Although felids have been considered reluctant to enter cage traps, Woolf and Nielsen (2002) reported that bobcats (*Lynx rufus*) were twice as easy to capture in cage traps versus foothold traps. Trap injuries were uncommon in cage traps and included only minor cuts or bruises. Radio monitoring revealed that bobcats resumed their normal activities within 24 hr.

Canids appear truly reluctant to enter cage traps. They, felids, and the largest mustelids can be trapped with foothold traps and foot-snares, which must be matched in size to the target species to minimize injuries. Properly chosen foothold traps, especially padded traps, may meet Criterion II (Proulx 1999a; Seddon et al. 1999). Long-spring number 1½ foothold traps set for arctic foxes (*Alopex lagopus*) meet Criterion II if checked daily (Proulx et al. 1994). Many foothold traps with padded jaws meet Criterion II to capture other foxes (*Vulpes* spp.), coyotes (*Canis latrans;* Onderka et al. 1990; Phillips et al. 1996), bobcats (Olsen et al. 1988), and otters (Serfass et al. 1996).

The Åberg (Nordic Sport AB, Skellefteå, Sweden) and Fremont (Fremont Humane Traps, Beaumont, Alberta) snares can capture canids without causing serious injuries (Englund 1982; Onderka et al. 1990), and the Fremont (Mowat et al. 1994) and Schimetz-Aldrich (D. Schimetz, Sekiu, Washington) (Logan et al. 1999) snares also meet Criterion II for felids. The Belisle and the Wildlife Service snare systems used to capture coyotes appear not to meet Criterion II (Shivik et al. 2000).

Sets that minimize capture of nontarget animals must be developed. Nontarget animals, especially those smaller than the target species, can be severely injured in foothold traps. Traps set for small carnivores must be anchored well enough to withstand capture by large, nontarget carnivores; otherwise, a large carnivore may escape carrying a small trap on its paw.

Mustelids can be kill-trapped in powerful snap traps (e.g., the Bionic), in planar traps (e.g., the Kania 2000), and in rotation-jaw traps (e.g., C120 Magnum), which meet Criterion I. Arctic foxes and lynxes can be killed effectively in the Sauvageau 2001-8 (Les Pièges du Québec Enr.) and the modified C330, respectively, which meet Criterion I (Proulx 1999a). Other small to medium-sized carnivores can be trapped with the EGG trap, foothold traps, or foot-snares and killed humanely when found in traps. Sometimes medium-sized carnivores can be killed humanely by sharpshooting (Kreeger et al. 1990).

Researchers experienced with the natural history of the mammals they study recognize potential trapping sites. The presence of scats or tracks often call for placing a trap. Special habitat features such as snags, coarse woody debris, nearby dens, squirrel middens, snowshoe hare trails, and proximity to water usually provide researchers with successful trapping sites (Buskirk and Powell 1994; Hubert et al. 1996; Woolf and Nielsen 2002). For some research designs, superimposing a grid of appropriate cell size on a map of the study area and putting a trap in appropriate sites in each cell provides good sampling.

Large Carnivores and Omnivores

The category of large carnivores and omnivores includes the large felids, hyaenids, canids, and ursids. Large felids (e.g., mountain lions [*Puma concolor*] and tigers [*Panthera tigris*]) can be captured in foot-snares without serious injuries (Goodrich et al. 2001; Logan et al. 1999). Wolves, coyotes, and other large canids are most often trapped with foothold traps or foot-snares (Bjorge and Gunson; 1989, Onderka et al. 1990). Chosen and used properly, foothold traps set for large canids and felids can meet Criterion II. Neck-snares with tranquilizing tabs have been used for coyotes (Pruss et al. 2002), and drive nets have been used for wolves with less injury than foothold traps (Okarma and Jedrzejewski 1997). Although drive nets may not be practical for many studies, they should not be summarily dismissed without being investigated as an option. Multiple capture cage traps set at den entrances can be effective for capturing coyote pups (Foreyt and Rubenser 1980). Wolves and other large mammals have been recaptured using radio telemetric collars outfitted with darts (Mech et al. 1984; Powell et al. 1997), and this capture appears to meet Criterion II when used for black bears (Powell, unpublished data).

Brown hyaenas (*Hyaena brunnea*) can be captured using cage traps (Mills 1990), and spotted hyaenas (*Crocuta crocuta*) using darts fired from specially built air rifles (Frank 1986, Mills 1990). Care must be taken with these firearms to hit a large muscle mass with the dart to avoid serious injury.

Bears are trapped in cumbersome but effective barrel and culvert traps (Graf et al. 1992). Most culvert traps have a heavy guillotine door that drops when a bear pulls bait from a trigger. A door can kill a cub following its mother into a trap. Because each trap is made individually and is different from others, each must be compared separately with Criterion II. One barrel trap used by Powell (unpublished data) to trap black bears met Criterion II, but capture of a bear in another barrel trap caused extensive tooth breakage. These traps are difficult to transport and cannot be distributed effectively across most back-country study areas.

Bears can also be captured effectively in foot-snares modified with an automobile hood spring for cushioning (Graf et al. 1992; Huber et al. 1996; Johnson and Pelton 1980; Powell et al. 1997), which can be transported far into back country, allowing effective sampling in remote study areas. Bears captured in foot-snares often struggle energetically and much more than bears in barrel traps. If branches, logs, or small trees tangle in the snare cable, cushioning devices may not work and bears may break bones or the cable may cut into the captured paw. Otherwise, common trap injuries rarely extend beyond swelling and minor cuts or abrasions. Foothold snares used by Powell (unpublished data) met Criterion II; most bears were physically exhausted but had no long-term effects. Small bears captured in snares can be, unfortunately, subject to predation by large bears. Consequently, where bear densities are high and big bears frequent traps, foot-snares may not be tenable.

In US states where hunting with dogs is legal, researchers have hired hunters and their dogs to tree black bears and mountain lions, where the animals can be drugged (Hornocker 1970; Ruggles 2002; Seidensticker et al. 1973). These predators may become physically exhausted, and drugged animals can be injured when being lowered from trees, yet the technique has not been evaluated relative to Criterion II.

Baited sets strategically placed along trails and watercourses may be more effective than blind sets to capture large carnivores and omnivores that are naive. These mammals are highly intelligent, however, and trap-wise carnivores and omnivores can be extremely difficult to recapture and often require trail sets that bear no human scent.

For studies requiring animals to be killed, these large carnivores and omnivores can be live-trapped and killed humanely once captured. Sometimes they can be killed humanely by sharp-shooting.

Marking Mammals

For most research on wild mammals, individuals that have been trapped must be identifiable on recapture or from a distance. Tasks such as estimating population sizes, calculating demographic variables, and discerning behavior of individuals all require that individual animals be identifiable. Use of natural marks is preferred where feasible, although lack of obvious marks, secretive behavior, and dense habitat usually preclude using natural marks to identify mammals.

When marks are applied, whether temporary or permanent, they should be as painless as possible and should not affect the animals' behavior or health (ASM/ACUC 1998). Marks must be matched to research objectives and must be appropriate for the mammals' sizes, future growth, body shapes, and behavior. A variety of short-term, long-term, and permanent markers are available, some of which have been evaluated specifically for their effects on research animals. Researchers should carefully investigate the use of anesthetic drugs to facilitate handling.

Short-term Markers

Short-term markers usually persist less than a year. They include marks lost during subsequent molts, nocturnal lights, chemical products that are shed after short periods, and body attachments.

Fur clipping and dyeing. One can mark small mammals temporarily by shaving unique patterns in the hair on their backs. This technique is particularly useful to mark shrews that cannot be ear-tagged (Sullivan 1997). Dyed hair can be used to mark mammals of all sizes in the same way (Hanks 1969; McCracken 1984; Ramsay and Stirling 1986;

Shriner and Stacey 1991; Singer 1978). Dyes are particularly useful for mammals of light pelage, although the range of colors is small. Yellow picric acid and pink Rhodamine B have been used to mark lagomorphs (Brady and Pelton 1976; Keith et al. 1968), mountain beavers (*Aplodontia rufa;* Lindsey 1983), and other animals (Fisher 1999). The effects of changing a mammal's hair coat are unknown and may alter cryptic coloration and hence predation, thermoregulation, and a mammal's ability to deal with weather and its physical environment.

Nocturnal lights. "Pinlights" and "flashers" taped to the fur of nocturnal mammals or to collars allow researchers to follow them (Barbour and Davis 1969; Batchelor and McMillan 1980; Carpenter et al. 1977). The duration and intensity of the markers depend on the size and life span of the batteries.

Powders. Fluorescent powders are used to detect the presence and movements of small mammals (Lemen and Freeman 1985; Jike et al. 1988; Proulx et al. 1995a). The fluorescent powder trails left by mammals are detected by portable, ultraviolet lights. Reliability of detection varies with vegetation cover and precipitation (Mullican 1988).

Body attachments. Streamers and colored disks of different lengths and color codes attached to a mammal's body or to eartags allow identification of animals from a distance (Aldous and Craighead 1958; Daan 1969; Knowlton et al. 1964; Lentfer 1968; Queal and Hlavachick 1968).

Punch-marking. A tattoo instrument normally used to mark domestic livestock can punch small holes in unique patterns (numbers) through the outstretched wing membranes of bats (Bonaccorso and Smythe 1972). Punch marks remain legible for only about 5 mo (Bonaccorso et al. 1976).

Long-term Markers

Long-term markers include eartags, collars and bands, passive integated transponder (PIT[1]) tags, radioactive markers, and beta lights. Brief descriptions of markers in this category appear below.

Eartags. Eartags made from metals or plastics of all shapes, sizes, and colors and stamped with codes are the mark of choice for many mammals (Proulx and Gilbert 1983; Smith and Gao 1991; Steigers and Flinders 1980; Stirling 1989; Sullivan 1997). Fingerling ear tags have been used to mark bats since the 1930s (Mohr 1934) but are not suitable for large-eared bats that exhibit rapid ear movements synchronized with echolocation (Stebbins 1978). Eartags can also be applied to interdigital webbing (Keith et al. 1968), to the outer toes of the hind feet (Linduska 1942), or to the skin of mammals' backs (Errington and Errington 1937).

Eartags should be loose enough not to interfere with blood circulation, and puncture marks should be treated appropriately to prevent infection and ensure healing (Nietfeld et al. 1994). Eartags can be pulled out by animals grooming each other (Stirling 1989) or can catch on vegetation (Proulx, unpublished data). Turning metal, crimping eartags in a mammal's ear so that the clasp is outermost appears to minimize loss (Powell, unpublished data). Using redundant marking overcomes problems from tag losses. Eartags may inhibit grooming and lead to infestations of mites and ticks (e.g., Ostfeld et al. 1996).

Collars and bands. Neck collars, fixed in size or expandable for growing animals, have been used to mark many mammal species (Beale and Smith 1973; Hawkins et al. 1967; Rudge and Joblin 1976). Neck collars outfitted with radio transmitters allow identification of individual animals and their movements. Neck collars must be sized carefully to be loose enough not to cause injury or skin irritation. Wing bands or bead-chain necklaces are best for bats (Barclay and Bell 1988). Researchers must be familiar with the many special requirements for bands and necklaces on bats (Barclay and Bell 1988; Bonaccorso et al. 1976; Handley et al. 1991; Kunz 1996).

PIT tags. Pit tags provide permanent identification. Each tag consists of an electromagnetic coil and custom-designed microchip that emits an analog signal when excited by electromagnetic energy from a scanning wand. The transponder chip is uniquely programmed with an alpha or numeric code, and > 34 billion combinations are available (Nietfeld et al. 1994). Once inserted under a mammal's skin with a large bore syringe, a PIT tag can be "read" by a scanner. PIT tags are expensive, however, relative to most other marking methods, and they require a specific scanner matched to the tag type to read the identification. PIT tags may wander under an animal's skin, especially on large mammals. Nonetheless, PIT tags may be more reliable than eartags on some small mammals (Harper and Batzli 1996; Williams et al. 1997).

Radioactive markers. A variety of mammals have been marked with radioisotopes as inert implants, external attachments, and metabolizable radionucleoides (Linn 1978; Nellis et al. 1967; Pelton and Marcum 1975). When using radioactive tags, researchers must follow established federal safety standards.

Betalights. A betalight is a phosphor-coated glass capsule containing a small quantity of mildly radioactive tritium gas. When the phosphor is struck by low-level beta radiation from tritium, it produces visible light of a characteristic color (Rudran 1996). Betalights can be incorporated with other markers (Cheeseman and Mallinson 1980; Davey et al. 1980; Hardy and Taylor 1980). They appear to pose no appreciable health hazard due to radiation and may function for years (Rudran 1996).

Permanent Markers

Permanent markers include natural markings, mutilations, freeze branding, and tattoos. Brief descriptions of the markers in this category appear below.

Natural markings. The size, shape, or peculiarities of, for example, natural body marks, horn characteristics, and scars may be used to identify individual mammals (Kelly 2001; Mukinya 1976; Pennycuick 1978).

Mutilations. Toe clipping, where the claw and first joint of the toe are removed with dissecting scissors, is an inexpensive, rapid, and permanent marking technique (Blair 1941). This technique is suitable for small mammals when no other marking methods are appropriate (ASM/ACUC 1998). Toe clipping is judged unethical by some researchers (e.g., Sullivan 1997) and may (Pavone and Boonstra 1985) or may not (Montgomery 1985) decrease the life span of some small mammals. It may, however, be less detrimental than eartags and other marks for other small mammals (Ostfeld et al. 1996). It is not recommended for bats (Barclay and Bell 1988).

Ears may be punched or clipped in a variety of coded systems (Blair 1941; Honma et al. 1986; Kruuk 1972). Punched holes or slits cut into foot webs have been used to mark beavers (Aldous 1940) and nutrias (coypus; Davis 1963). Natural holes and cuts in ears can sometimes be confused for punched holes, making these marks not unique for some mammals (e.g., *Peromysucs* spp. and black bears; Powell, unpublished data).

Freeze branding. Freeze branding, or cryobranding, applies either a copper branding iron that is supercooled in liquid nitrogen, a mixture of dry ice and alcohol, or a commercial refrigerant to an area of the body (Hadow 1972). Performed correctly, freeze branding kills the pigment-producing melanocytes of the skin but not the hair follicles, so the hair and skin that grow back in the branded area are permanently white (Day et al. 1980; Hadow 1972). Freeze branding can produce diverse, unique marks (Hadow 1972; Newsom and Sullivan 1968; Pfeifer et al. 1984; Rood and Nellis 1980; Sherwin et al. 2002); proper timing of a freeze brand varies with animal species, however, and producing dependable brands requires experience.

Tattoos. A tattoo, applied with special pliers or an electric tattooing pencil, is a series of tiny perforations in the skin into which a dark dye is rubbed or injected to produce a visible pattern. Any body part that is relatively free of hair and remains fairly clean can be tattooed. Animals of all sizes can be tattooed, from small mammals to deer and bears (Carnio and Killmar 1983; Downing and McGinnes 1969; Honma et al. 1986; Keith et al. 1968; Smythe 1978; Stirling 1989).

Conclusion

Research that involves trapping of mammals contributes to significant increases in our knowledge of evolution, ecology, animal behavior, physiology, parasitology, and genetics. Traps used in research should meet performance criteria that address state-of-the-art trapping technology and that optimize animal welfare conditions within the context of the research. Good research design should integrate ethics, performance criteria, techniques, and common sense, and IACUCs should address these topics when evaluating research protocols. Researchers must always work to improve research methods and to decrease the effects on research animals, if for no other reason that to minimize the chances that research methods affect the animals' behavior in ways that affect research results.

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SPECIES PLANNING: AN APPROACH TO BLACK BEAR MANAGEMENT AND RESEARCH IN MAINE

ROY D. HUGIE, Maine Department of Inland Fisheries and Wildlife, 236 Nutting Hall, University of Maine, Orono 04473

Abstract: The Maine Department of Inland Fisheries and Wildlife began the active phase of comprehensive species planning in 1974 and implemented the resultant plan for black bears (*Ursus americanus*) in 1975. The black bear's past, present, and projected future status were evaluated in terms of interrelationships among population, density, distribution, habitat, use-demand, and use-opportunity. Alternate goals and objectives were formulated for presentation to wildlife professionals, administrative personnel, and selected segments of the public. The goal set for the black bear was to maintain 1970-74 levels of abundance, distribution, and use. The objective was to provide for an annual harvest of about 800-1,000 bears by 30,000 hunters statewide, with maximum allowable harvest differing according to management units. Experience thus far indicates that comprehensive species planning has greatly benefited black bear management in Maine and can be highly recommended for other areas.

This paper provides a brief background of the status of black bears in Maine and describes the comprehensive species-planning process as it involved bear management and research. Special acknowledgment and thanks go to C. Banasiak, J. Kienzler, J. Hermes, G. Lavigne, and A. Clauson for their work on the bear project.

There has not been a nationally disseminated report on bears in Maine since 1955. What has happened during the last 2 decades will serve as an introduction to the planning process. Black bears were once common throughout New England, but since the late 1700s, they have generally decreased in numbers and distribution (Cardoza 1976). At present, Maine is one of the major strongholds of black bears in the East, with about 59,000 km^2 (72 percent) of the state's land area still occupied. From 1770 to 1957, there was no closed season, no limit, and a bounty on black bears in Maine. From 1957 to 1965, there was no limit and no closed season. From 1966 to 1968, there was a season from June through December but no limit. During 1969-74, there was a 6- to 7-month season with a limit of 1 bear per hunter per year. The seasons of 1975 and 1976 ran from 1 May through 30 November. Legal hunting methods are very liberal; trapping with foot snares or conventional traps, baiting, using dogs to track and chase, and shooting bears incidental to other types of hunting are all legal. The average annual recorded bear kill from 1946 to 1959 was 1,569. From 1970 to 1976, the average registered bear kill was 930, ranging from 1,071 in 1973 to 744 in 1974. Other than keeping track of the legal kill through a mandatory registration system, there was virtually no research done on black bears in Maine from 1954 to 1974.

COMPREHENSIVE SPECIES PLANNING

The Maine Department of Inland Fisheries and Wildlife embarked on comprehensive species planning in 1968, although active planning did not begin until 1974. The effort involved all fish and wildlife species in the state and was guided and administered by the Planning Division of the Department. The program was funded by Pittman-Robertson monies.

A comprehensive planning effort requires much time and money. Ongoing projects were temporarily cut back or halted. The advantages of, and reasons for, implementing research and management policy through a comprehensive planning approach were given by Kennedy (1976), Richards (1976), and Woodgerd (1976). For the Maine program, the justifications were (1) to delineate in one document a species' past, present, and future status with regard to habitat, abundance, distribution, use, and importance; (2) to engineer a management goal and objective that would have input and support from wildlife professionals, administrative personnel, and the public (including nonsportsmen and antihunters); (3) to provide a strategy and a specific program especially designed to achieve a selected goal and objective; (4) to establish a system and a source for giving input into external (non-Department) plans, programs, projects, and other activities that might have an impact on a species; and (5) to maintain continuity in management and research. In short, the purpose was to develop a plan to avoid "management by whim or crisis."

Maine's species plan for the black bear required 18 months to develop. The first step was the assembling of all the available historical data and information regarding black bears in Maine. Most of the history came from old periodicals, journals, and Department records. Next, life history information that was pertinent to management was collected from past research (Spencer 1955), current data from Maine (Hugie

1974), and applicable findings from black bear research conducted outside Maine. A lack of data on any aspect of the species did not stop the planning process. In fact, implementation of programs to obtain basic life history data became an important part of the final plan.

Next, the present status with a specific base year for population, density, distribution, habitat, use-demands, use-opportunities, and the relationships between and among those parameters were summarized from existing data and criteria. Maine harvest data, density estimates from studies outside Maine, and the sex- and age-specific data on hand were used to make rough estimates of the population. The estimates ranged from 7,000 to 10,000 animals. A distribution map of occupied range was made, based upon registration data and questionnaires. Demand was measured in terms of harvest during 1970-74. Use-opportunity was expressed in terms of square kilometers available to the public for consumptive and nonconsumptive demands. Available information suggested that the annual harvest should be no more than 15 percent of the minimum population or 1,050 bears.

The same parameters were then evaluated in terms of the future. Trends in human population growth and shifts in land-use practices were projected for the next 15 years at 1970-73 rates. Habitat, use-opportunity, and supply were projected to decrease but demand was projected to increase. Thus, an unsatisfied demand for consumptive use of bears was estimated to occur as early as 1985.

With the past, the present, and the future in mind, several alternative goals and objectives were written by the plan author. Goals were broad — descriptions of what the distribution, abundance, and use of the bear resource should be in 1990. Objectives were more specific regarding levels of use, areas of distribution, and levels of abundance.

The next step was perhaps the most crucial of the entire process. alternative goals and objectives were presented to biologists within the Department, Department administrators, a political advisory council, a selected steering committee, the university community, several non-Department biologists, and other interested individuals. The steering committee was selected to provide balance among geographical and interest groups. If I were to go through the process again, I would seek out as many interested vocal minorities as possible for their input into the selection of goals and objectives. I firmly believe that success of a management program demands broad base support that can only be attained through honest and open communication during the stage of public involvement. In my judgment, the so-called "controlled sanction approach" common to many state, federal, and provincial agencies with regard to soliciting and using public input is not effective. The importance of widely based public involvement increase when managing a controversial species like the black bear.

The goal agreed upon by these groups was to maintain black bear abundance, distribution, and use at 1970-74 levels. The objective was to provide for an annual harvest of approximately 800-1,000 bears by 30,000 hunters statewide, with a maximum harvest for each management unit of no more than 15 percent of each unit's minimum estimated population.

Once the goal and objective were chosen, it was obvious that specific problems would hinder attainment of the objective. Major problems were an absence of reliable data on population size, hunting pressure, rates of exploitation, habitat requirements, illegal kill, and distribution status in areas of low bear density. Also, legislative and administrative guidelines and authority were needed for controlling use in specific geographical areas. These problems were defined and a strategy for resolving them was developed. The strategy section of the black bear plan included a series of comments that states what was to be done, in what order, and why. Not all of the aspects of the strategy were designed to be implemented at once. Rather, the strategy defined a series of accomplishments leading toward the attainment of the goal and objective. The strategy gave special consideration to public awareness, public involvement, and legislative programs.

Although the strategy section described what was to be done to reach the goal and objective, specific jobs and programs were needed to prepare for actual implementation of the management plan.

More programs and jobs were proposed for funding than the Department's financial resources could support. Therefore, a comparison of all the species plans and their respective strategies and jobs gave administrative personnel and the biological staff an opportunity to select for immediate funding those jobs with highest priority. Approximately two-thirds of the new jobs proposed were funded.

CONCLUSION

The actual implementation of proposed black bear jobs was initiated in 1975. Comprehensive species planning has not solved all of our bear management problems but it has been extremely helpful. The species planning and management process now includes a continual updating procedure as new data become available. Some of the benefits of the process have been the setting of specific objectives, the formulation of clearly defined plans of actions, assured direction and continuity of purpose and effort, and, above all, the provision of a vehicle for continuous refinement of bear management in Maine. I believe that the effort was very worthwhile despite the expense, man-hours, and temporary inconvenience to existing programs that the process entailed. Once the status and importance of bears to the state and to the Department had been made clear, comparison of expenditures was easier. The budget and manpower for bear management rose from $2,000 per year with 1 part-time person to over $40,000 per year and 2½ man-years of effort after the planning stage. Comprehensive planning has facilitated a giant step forward in bear management and research in Maine. I highly recommend similar efforts wherever black bear management and research objectives are unclear or strategies ill-defined. The results and findings of Maine's black bear management and research programs are found in the Pittman-Robertson reports for W-67-R-2 (Hugie 1974, 1976, 1977; Kienzler 1975). A detailed outline of the process may be obtained from the Maine Department of Inland Fisheries and Wildlife, Planning Division, 284 State Street, Augusta 04333.

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Black Bear Population Assessment Methodology and Data Analysis In Nevada: A Review

Nevada Department of Wildlife - 2011

Introduction

In response to increased bear-human conflicts the Nevada Department of Wildlife (NDOW) invigorated its black bear program in 1997 when it began actively altering the way it responded to and resolved these conflicts. This included a new policy, *Bear Conflict Management* (1998, revised 2007) and a public education campaign, *I'm Bear Aware, are you?* These facilitated a change in how NDOW handled individual bears. Captured bears considered candidates for release were tranquilized, marked and data recorded. Additionally, conflict bears were routinely released on-site with aversive conditioning rather than being relocated. Wildlife aversion conditioning management was a fairly new technique in 1997 and NDOW was one of the leaders in developing its use. These changes resulted in greater public involvement in the bear program and much more information on the black bear population being collected. The steady increase in bear-human conflicts raised questions about the bear population and these questions became the basis for the on-going long-term study that began in 1999. This research, together with a study from 1987-1990, has resulted in one Master's Thesis, one PhD dissertation, six peer-reviewed articles in professional scientific journals and two Biological Bulletins. These scientific publications cover a variety of topics such as population demographics, reproduction, genetics, aversive conditioning, relocation, denning chronology and home range size, as well as age-specific mortality, fecundity and survival rates of females. The following is a description of the process and methodology used to assess the black bear population in Nevada.

Data Collection

Adhering to the Department's nuisance bear policy and in cooperation with NDOW's research partners, Dr. Jon Beckmann of the Wildlife Conservation Society (WCS) and the University of Nevada, Reno, data have been collected in a rigorous manner on all black bears handled by agency personnel since 1997. This includes every bear that was captured and released or captured and euthanized, and new bears that were recovered as mortalities. Bears were captured in both urban and wildland areas using culvert traps, foot snares or free-range techniques. The data set contains information on date, sex, age, weight, color, physical condition, reproductive status, morphological measurements and conditions of every capture or mortality event. Biological samples taken from individual bears include hair, whole blood, serum and tooth samples. Additionally, this data set contains temporal and empirical data from individual bears wearing VHF, GPS and satellite collars. A summary of the data set is as follows:

- 481 individual bears
- 832 incidences (captures, recaptures, recovered mortalities, etc.)
- 36 percent average recapture rate of marked bears
- 85 collars deployed
- 187 females
    - ✓ average age adults = 8.0 years

- 284 males
  - ✓ average age adults = 6.5 years
- 124 cubs
- 295 documented mortalities in Nevada including:
  - ✓ 85 public safety/chronic nuisance
  - ✓ 147 hit by cars
  - ✓ 20 depredation
  - ✓ 5 illegal
- Beckmann reported urban areas in Lake Tahoe Basin on the Nevada side had the second highest reported density of black bears in North America (Beckmann and Berger 2003a).
- Bears captured through May of 2002 were classified as urban (n=71) or wildland (n=28), based on their proportion of time spent in urban areas. The differences noted here were behavioral only and do not suggest two different breeding populations of bears (Beckmann and Berger 2003b). Since 1997 bears have been marked with tattoos, ear-tags and many were also radio-collared. Defining bears as urban or wildland using the criteria described in Beckmann and Berger (2003a) is only possible for radio-collared bears.
- In 2008 the focus of ongoing long-term research shifted more towards wildland bears. Since that time data have been collected on 12 wildland males and 22 wildland females.

Data Analysis

The data used to generate the latest bear population demographic figures include:

- Data collected from 1997 through 2008 (12 years).
- 709 total occurrences (each time a bear was handled counted as an occurrence).
- 420 individual bears in the data set that was analyzed.

Note: More than half of these bears (223) were removed from the final analysis because they did not meet the criteria of the analysis program.

- 197 bears were represented in the final analysis by Dr. James Sedinger (University of Nevada, Reno) compared to 58 bears in a previously published analysis by Beckmann (Beckmann 2002, Beckmann and Berger 2003a). This increase of available data in the data set was reflected in lower confidence intervals as well as the noted change in the bear population estimate.
- We used the Jolly-Seber method (Jolly 1965, Seber 1965, Seber 1986) in Program MARK (White and Burnham 1999) to calculate:
  - ✓ Quarterly survival
  - ✓ Annual survival
  - ✓ Seasonal capture probabilities
  - ✓ Population estimate
  - ✓ Rate of recruitment
  - ✓ Finite rate of increase

Black Bear Population Dynamics Estimation Procedure

The following summary of the black bear population dynamics estimation procedure used by NDOW was prepared by Dr. James S. Sedinger, a population ecologist with the Department of Natural Resources and Environmental Science, University of Nevada Reno:

I estimated size of the black bear population in the Carson Range, Lake Tahoe and the Reno-Carson City areas, and rate of change of the population using data from individual bears marked by NDOW staff. I conducted analyses using a software program, Program MARK, designed by Dr. Gary White, Colorado State University. Dr. White is an acknowledged expert in estimation of demographic parameters from wildlife populations. I explain these estimates below.

I estimated size of the population using the Jolly-Seber method. This approach uses the following logic. A sample of animals is captured, marked and released. A second sample is then captured. If the first sample mixed with the entire population the ratio of marked animals to the size of the total sample in the second sample is the same as the ratio of total marked animals (from the first sample) to the size of the entire population. If the size of the entire population is N (which we don't know but are trying to estimate), the number of marked animals released in the first sample is M, the size of the second sample is n and the number of marked animals in the second sample is m, we can write a formula for our estimate of population size as:

$$\frac{\mathrm{M}}{\mathrm{N}} = \frac{\mathrm{m}}{\mathrm{n}}$$

$$\xrightarrow{yields} \mathrm{N} = \frac{\mathrm{Mn}}{\mathrm{m}}$$

The Jolly Seber approach is a little more complex because it allows for mortality between the first and second samples (which it adjusts for), and combines the results from multiple samples. The basic logic of the calculation remains the same. It is important to note that these approaches generally produce underestimates of population size. If the first marked sample did not randomly mix, or if some individuals have a greater chance of being caught than others, population size will be underestimated. To see this, think about what happens if some individuals are more catchable. This will cause m, the number of marked animals in the second sample to be too large, because animals caught the first time are more likely to be caught the second time than expected if all animals are equally catchable. This will cause the ratio m/n to be too large, or n/m to be too small. If n/m is too small our estimate of N will be too small.

I estimated the rate of change in the size of the population, λ, using analyses of data from marked animals developed by Roger Pradel. Pradel analyses rely on the pattern of encounters of marked bears. NDOW marks each unmarked bear when it is captured and records all subsequent captures of each marked bear. The data are then structured so a marked bear receives a 1 each time it is caught and a 0 when it is not caught. We defined capture occasions as the 3 month seasons, defined by the solstices and equinoxes. If a bear was caught in a particular season it received a 1 for that season, if not, it received a 0. The analyses produced four kinds of parameters: survival, recruitment, capture probability and λ, the rate of population increase. Capture probabilities are estimated based on the proportion of bears that are missed on a particular occasion but captured later. Survival is estimated from the bears that are never caught again after a particular occasion, after accounting for the probability that some bears were never caught again even though they were alive (accounting for the fact that the capture probability was not 1 for any given season). Estimates of recruitment are based on when individuals first appear in the data (the season when they receive their first 1), accounting for the fact that some bears were present for some period before they were first detected (those capture probabilities again). Rate of population increase just represents the sum of per capita recruitment and survival, and can also be *thought of as the ratio of the number in the population in one year divided by the number in the previous year. That is, λ is the proportional increase in the population from one year to the next. A λ greater than 1 indicates the population is increasing, while a λ less than 1 indicates the population is declining.*

Based on this analysis Nevada's bear population in the study area (core population) was estimated to be between 200-300 adult animals at the end of 2008. The rate of population increase as described above was estimated to be approximately 16% annually. Quotas for the bear hunt were recommended using these figures based on the concept of *sustainable yield.* Sustainable yield can be described as the ecological yield (number of animals) that can be removed without reducing the base population. Depending on management goals, the surplus can be managed to maintain the population at the same or an increasing level over time. The recommended quota of 20 bears represents only 50% of the sustained yield estimates for the core bear population. Based on this recommended level of harvest continued growth of Nevada's bear population can be expected.

The estimate for Nevada's portion of the Sierra black bear population has been determined to be conservative because of the following : (1) heterogeneity in the capture probabilities – not all bears had an equal chance of capture; (2) the population estimate represents the core population as described above, but viable populations exist elsewhere and were not represented proportionately in the data set; and (3) 223 bears captured in Nevada were removed from the analysis because of the criteria chosen, even though they were part of the population at the time of their occurrence.

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There is no question that poaching is a big threat of the survival of many wildlife in this region including sun bear. Saving wildlife from the hand of poachers is not just the job for law enforcement agencies but a responsibility for all of us at difference levels in the society. In development countries such as all the range countries of sun bears in SE Asia, enforcement of wildlife protection laws is not a high priority because of limited resources and lack of interest from the authorities. This is why the participations by people ranging from local communities to international NGOs and individual is becoming even more important, if we were to combat poachers and save our wildlife from extinction.

Please report any unlawful poaching and wildlife exploitation activities to the local wildlife authorities. If you have more information about poaching, snaring, and other illegal activities on sun bear, please contact me at wongsiew@hotmail.com or calling +60 16 555 1256.

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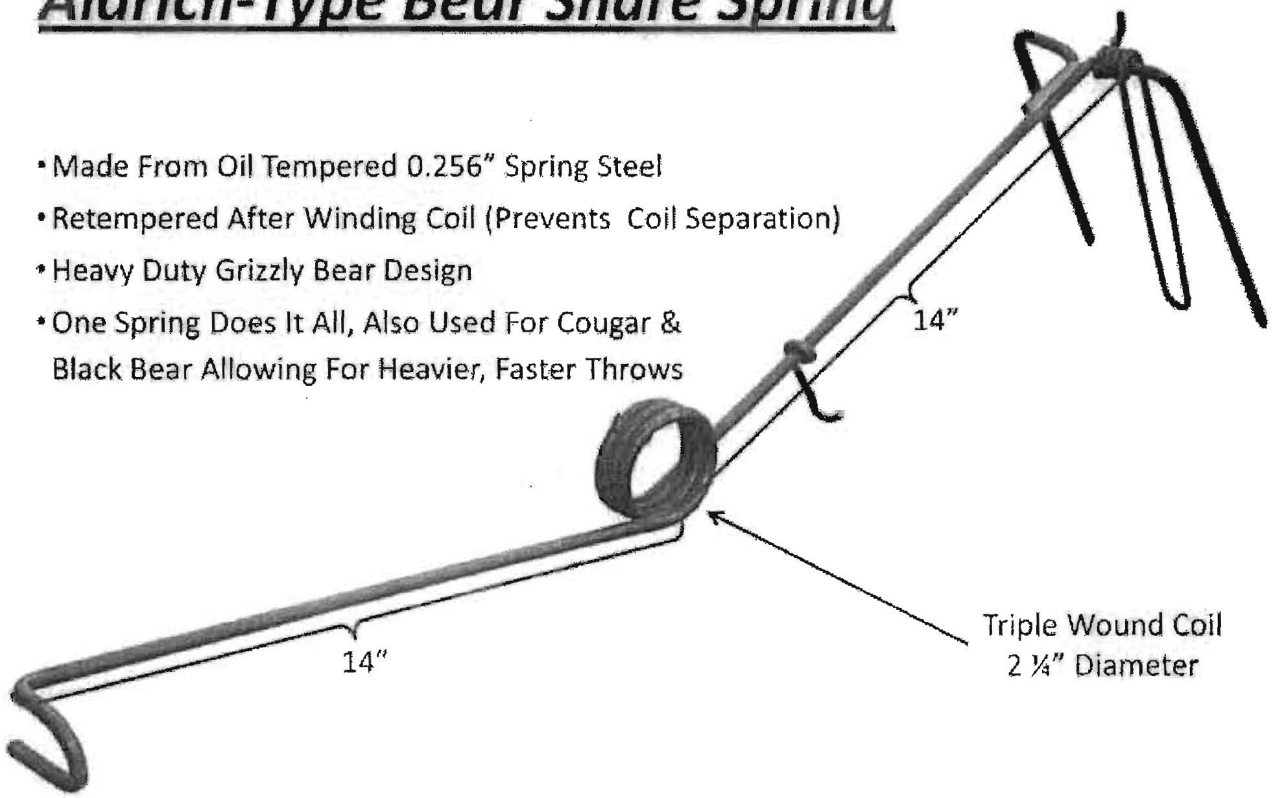
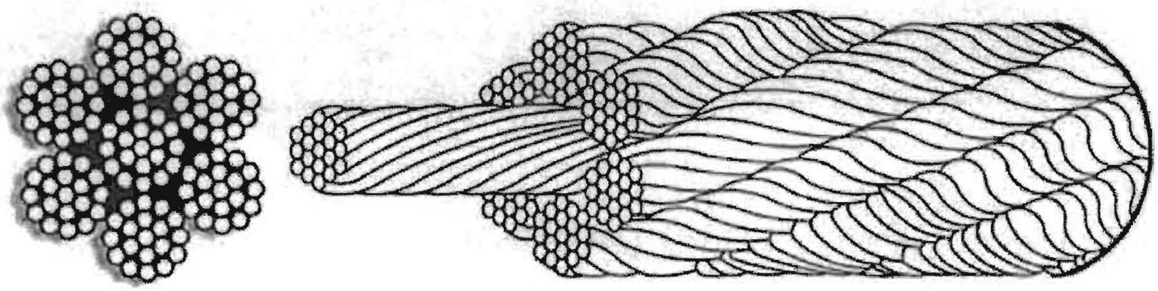


7 x 19 Galvanized Cable



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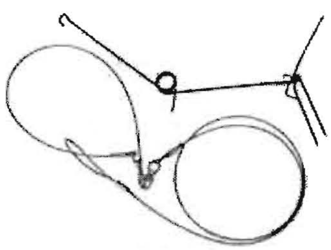

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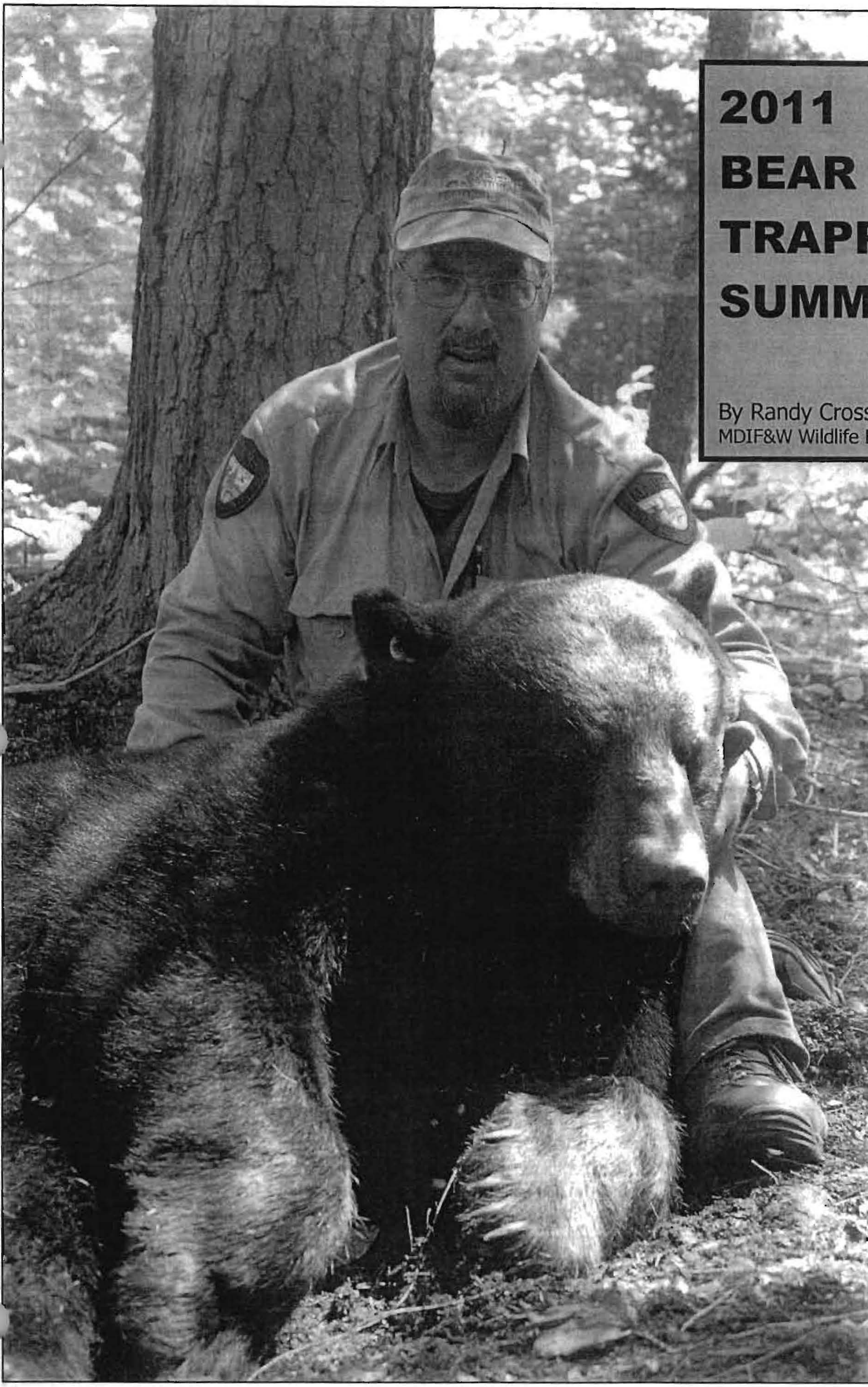
2011 BEAR TRAPPING SUMMARY

By Randy Cross
MDIF&W Wildlife Biologist



The 2011 Trapping Crew: Randy Cross, Contractors Dan Wagner, Lisa Bates and Jared Mitchell, and Volunteers Steve Dunham, Mike Ballinger and Joe Roy

Randy Cross holds "Tank," a 342-pound male.

Photo by Lisa Bates

MDIF&W Wildlife Biologist Randy Cross attempts to sedate "Tank" so he can evaluate the bear's health. "Tank" is a 342-pound male.

2011 Trapping Season Summary

By Randy Cross
Maine Department of Inland Fisheries and Wildlife Biologist

The 2011 trapping crew included myself with contractors, Dan Wagner, Lisa Bates, and Jared Mitchell and volunteers, Steve Dunham, Mike Ballinger and Joe Roy.

This spring was generally wet and cool. These conditions are favorable for bears, creating lush vegetation that is both highly digestible and abundant. This resulted in bears being less active on our baits with particularly low bait interest late in the trapping season.

We began tending snares on May 20 and continued 40 days to June 28. We set traps at 69 sites, 28 in Lagrange (24 caps), 26 in Edinburg (19 caps), and 15 in Howland (11 caps) (3,368 snare-nights - 62.4 SN/Cap). In comparison, the number of snare-nights required per capture averaged only 35.5 over the last 3 years we trapped this study area (2002, 2005, and 2009). Trapping success was the lowest experienced in at least 10 years.

"Kimbo" is a 352-pound male.

We confined most of our snares to a small area (less than 18 mi^2) in the northeastern portion of the study area. This is the same area that we trapped in 2009. In an ongoing effort to recalculate the bear density estimate for this area, we attempted to recover one GPS collar that we lost contact with and deploy more GPS collars on females.

We recovered the missing GPS collar (ID 2753), which had 669 locations stored in it from the summers of 2010 and 2011. We also placed GPS collars on 4 female targets, bringing our current total of GPS collared females to 6 in this study area. We hope to recover these collars in dens next winter in order to download the stored locational data. We also placed VHF collars on a yearling, a young female who had lost her collar, and a sub-adult near the edge of our focus area. We captured 14 of 23 females known to inhabit the area that was trapped (61%). We finished with 31 active collars on females in this study area.

Lisa Bates shows "Bomber," a 231-pound male.

Snares were tripped 263 times resulting in 54 captures of bears (33M/21F), 7 moose (including two calves), 1 coyote, 1 raccoon, and 1 hare. We captured 37 different bears (21M/16F), 10 of which were new to the study (8M/2F) and 27 were previously tagged (13M, 14F). 10 yearlings (6M, 4F) were captured a total of 17 times. We had 27 bear captures by day 9, ending with only 27 more captures during the remaining 31 days. We caught no bears on 20 of the 40 days we trapped.

We caught one lactating female (1237) and one female cub. We caught 2 males over 300 lbs, catching a total of 5,435 lbs of bear for the entire trapping period. We collected 39 hair samples which may be used for genetic purposes or physiochemical analysis.

We hosted 54 guests on 17 days including writers Al Raychard and Steve Carpenteri.

2010 MDIFW Black Bear Trapping Season Summary
Prepared by Randy Cross, Wildlife Biologist, MDIFW

As part of MDIF&W's ongoing black bear monitoring project, a team of biologists captured bears using foot snares northeast of Beddington this spring.Our team included MDIF&W wildlife biologist, Randy Cross, field crew leaders, Dan Wagner and Craig McLaughlin, wildlife field technician (contractor), Marcus Mustin with volunteers, Jared Mitchell, Everett Smith and Susan Bard.

We attempted to recover 6 GPS collars which had quit transmitting a signal as well as bolster the number of radiocollared females which are monitored to represent all bears living in similar habitats in the region. The GPS collars also had stored up to 900 locations from each bear's movements last year.

This spring came very early (many indicators were about 3 weeks ahead of average). Bears in this area entered their dens early last fall and many were lean this spring, resulting in active baits early with continued high interest through the trapping period. Weights of yearlings in their winter dens are our best indicator of the relative abundance of food the previous summer. Yearlings in last winter's dens here averaged 37 lbs. This is 16 lbs less than yearlings in our central Maine study area and 8 lbs lighter than yearlings in our northern study area last winter.

We began tending snares on May 13 and continued 43 days to June 24. We set traps at 92 sites, mostly in Townships 35 and 36 with a few sites in the very southernmost portions of T41 and T42 (under 50 sq miles). We captured twice as many males as females (65 male captures / 34 female captures – 99 in all). This 2:1 ratio of male to female captures is normal, even though there are more females than males in the population due to hunter selection of larger male bears, reluctance to harvest females with cubs and male bears' higher vulnerability to harvest. Males tend to be more vulnerable to snares set for research as well, due in part to their extensive traveling during breeding season (mostly, late May through July). We captured 72 different bears of which 28 were new to the study and 44 were previously tagged.

Twelve yearlings (9M, 3F) were captured 23 times.Bears identified as yearlings are about 15 months old with most weighing between 36 and 45lbs this spring in this area. Male yearlings tend to be a bit heavier than female yearlings and, as with adults, are easier to catch. Their inexperience and vulnerability to capture is well illustrated by one male yearling that was captured 5 times and his brother was captured 3 times (these two were bigger than the average weighing near 70 lbs each). We've found that many of the females in this area are reproductively synchronized – producing cubs on odd years and accompanied by yearlings in the spring during even years. We witnessed similar synchronous cub production in our northern study area (west of Ashland) during the 80's and 90's. Consequently, it wasn't surprising that we caught no lactating females or cubs this spring.

(Continued On Back)

As part of our ongoing effort to monitor reproduction in the area, we placed radiocollars on 16 females that either had no collar or had nonfunctioning collars, ending the season with 42 active collars on female bears, including 3 bears with GPS collars. This spring, we also captured 5 of the 6 bears whose GPS collars were not transmitting. We are using GPS collars to calculate the density of bears on this study area, The reliability of our density estimate is limited by our ability to capture the majority of the bears in the focus area. This spring was a particularly successful trapping season, as we captured 19 of 31 collared females (61%) known to inhabit the area that we trapped. We last trapped in this area in the spring of 2008.

An interesting side note, we caught 4 males over 300 lbs, one of which was over 21 years old (365 lbs). These bears will most likely gain somewhere near 200 lbs before entering their dens in late November. These older males are impressive, but as usual, around 70% of the bears captured weighed less than 150 lbs. The total weight of 99 captures was just over 13,000 lbs averaging less than 135 lbs per capture. On 5/26 we caught 5 bears totalling 1,251 lbs. We also collected 72 hair samples which may be used for genetic or physiochemical analysis.

Our monitoring of black bears on 3 study areas in northern, central, and eastern Maine helps us assess if we are meeting black bear population goals for conserving Maine's bear population, providing future viewing and hunting opportunities, and minimizing conflicts with bears. To learn more about black bears in Maine, visit http://www.maine.gov/ifw/wildlife/species/index.htm.

The Equal Access to Justice Act Law in 1990

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