AN ASSESSMENT OF INJURY TO EUROPEAN BADGERS (MELES MELES) DUE TO CAPTURE IN STOPPED RESTRAINTS

Authors: Murphy, Denise, O'Keeffe, James J., Martin, S. Wayne, Gormley, Eamonn, and Corner, Leigh A. L.

Source: Journal of Wildlife Diseases, 45(2) : 481-490

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-45.2.481

Journal of Wildlife Diseases, 45(2), 2009, pp. 481–490

AN ASSESSMENT OF INJURY TO EUROPEAN BADGERS (*MELES MELES*) DUE TO CAPTURE IN STOPPED RESTRAINTS

Denise Murphy,[1,4] **James J. O'Keeffe,**[2] **S. Wayne Martin,**[3] **Eamonn Gormley,**[1] **and Leigh A. L. Corner**[1]

[1] School of Agriculture, Food Science and Veterinary Medicine, College of Life Sciences, University College Dublin, Belfield, Dublin 4, Ireland
[2] Wildlife Unit, Department of Agriculture, Fisheries and Food, Agriculture House, Kildare Street, Dublin 2, Ireland
[3] Department of Population Medicine, Ontario Veterinary College, University of Guelph, Clinical Research Building, Guelph, Ontario N1G 2W1, Canada
[4] Corresponding author (email: denise.murphy@ucd.ie)

ABSTRACT: As part of ongoing culling operations, European badgers (*Meles meles*) were captured using stopped restraints in winter (October to December 2005) and summer (May to June 2006) in the Republic of Ireland. A subset of these badgers, those caught during four consecutive nights, was examined postmortem to determine the frequency and severity of physical injuries resulting from capture in the restraints. The skin and the tissues underlying the restraint of 343 badgers were assessed for injury by visual examination. There was an absence of skin damage or only minor skin abrasions in 88% of badgers; an absence of subcutaneous tissue injury or only localized subcutaneous tissue injury in 69%; and an absence of muscle injury or only slight muscle bruising in 99% of badgers. Only 2% of badgers had cuts to the skin and 5.5% had extensive subcutaneous edema, whereas 1.2% had areas of hemorrhage and tearing of the underlying muscle. Our results show that the majority of badgers examined sustained minimal injuries attributable to capture in stopped restraints.

Key words: Badger, capture, injury, *Meles meles*, stopped restraints.

INTRODUCTION

The European badger (*Meles meles*) is the principal wildlife reservoir of *Mycobacterium bovis* infection in the Republic of Ireland (Eves, 1999). Infection in the badger population contributes to the spread and persistence of tuberculosis in associated cattle herds (Gormley and Collins, 2000). The significant drop in prevalence of tuberculosis in cattle following the removal of infected badger populations in both the East Offaly study and Four Area study has clearly established the significance of the reservoir of infection in the badger population (O'Mairtin et al., 1998; Griffin et al., 2005).

In the Republic of Ireland, the badger is a protected species under national and international law and may only be removed under license. As part of the strategy to control bovine tuberculosis, badgers are removed where they have been identified as a probable source of an outbreak in cattle. Badgers are captured within a 2-km radius of the affected farm using stopped restraints made of multistrand steel wire wound around a core of nylon filament and designed to close to a minimum circumference of 28 cm. The stopped restraints have also been used in capture-release studies (Cheeseman and Mallinson, 1979; Southey et al., 2001). To date, no systematic studies have been undertaken to assess physical injuries arising from capture with stopped restraints. The aim of this study was to determine the frequency and severity of injury occurring when badgers were captured using stopped restraints and to identify potential risk factors for injury.

MATERIALS AND METHODS

We examined badgers removed during two culling operations, one conducted in winter (October to December 2005 [$n=198$]) and one in summer (May to June 2006 [$n=145$]). Badgers were obtained from broad geographic areas covering 16 counties. The study badgers were captured during four consecutive nights, Sunday through Wednesday. The stopped restraints were 3 mm in diameter, 143 cm in length, and were constructed of a multistrand steel wire wound around a core of nylon filament. The restraints were fitted with a stop mechanism to prevent them closing beyond a minimum circumference of 28 cm (DAFF, 1996). However, as part of this study, the stop distance of all restraints was recorded after capture. The restraint was secured in the ground with an angle iron and was held vertical by two wooden sticks with the base 1–2 cm off the ground. One or more restraints were placed in close proximity to the entrance of badger setts (badger setts are subterranean dens consisting of burrows that evolve into large labyrinths), whereas single restraints were laid on badger paths. Restraints were examined each morning after daybreak.

Badgers captured for the winter study were anesthetized with ketamine hydrochloride (0.1 ml/kg) and medetomidine (Domitor® 0.1 ml/kg), administered by intramuscular injection; blood was collected by jugular venipuncture, and the badger was then euthanized with an intravenous overdose of pentobarbital sodium. In the summer study, the badgers were euthanized by lethal gunshot. The badger carcasses were kept at ambient temperature for transport and thereafter stored at 4 C (if not examined postmortem within 12 hr). Most postmortem examinations were conducted within 24 hr of euthanasia (range, 8–48 hr). As part of the summer study, the location of the restraint in the environment (at a sett entrance or on a path), the terrain (flat ground or slope), the behavior of the badger on approach (resting, pacing, running, or thrashing), evidence of digging (yes or no) around the badger, the overnight weather conditions (wet or dry), and the physical condition of the restraint (smooth, few twists, very twisted, and/or frayed) were recorded.

We assessed restraint injury visually at postmortem examination and by histology. The conduct of the postmortem examination and the recording of observations were standardized to enable analysis of the results. The age (age classes: young [<18 mo], adult, or old, based on an assessment of tooth wear), sex, and body weight of each badger was recorded. The position of the restraint on the animal was recorded (Fig. 1), as was the badger's chest girth and restraint girth (girth of animal at level of restraint) and the stop distance of the restraint. The skin on the ventral surface from the chin to the pelvis was reflected, as was the skin from the sides and along the limbs. A classification scheme for injury was devised to standardize the description. The skin, subcutaneous tissues, and muscle were examined for gross pathology and classified by the degree of injury present (Table 1). In the description of muscle injury,

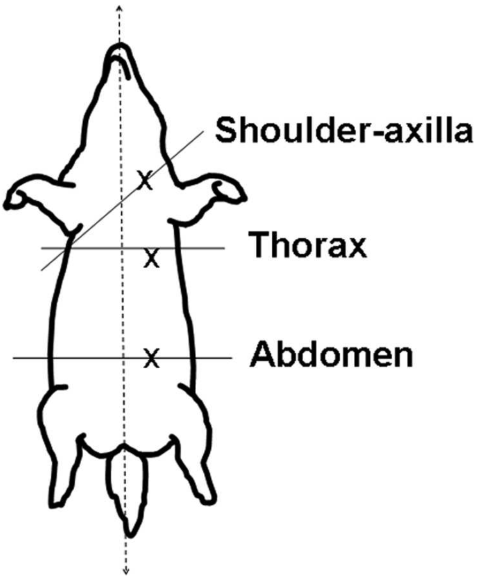

FIGURE 1. Positions of the restraints on captured badgers (*Meles meles*). Biopsy sites are indicated (X).

we included a category "hematoma," based on casual observations made as part of a previous study. Although it was injury at the site of the restraint that was primarily recorded, we also noted capture-related injuries at other sites on the body.

A skin biopsy (1 cm wide×3 cm long) was taken from a point approximately 3 cm to the left of ventral midline at the level of the restraint and fixed in 10% formalin (Fig. 1). The skin biopsies were sectioned at 3 μm and stained with hematoxylin and eosin. We examined histologic sections independently of the gross pathologic findings for evidence of epidermal necrosis, dermal hemorrhage, inflammation, and degeneration, and each parameter was scored independently on a scale of 0–4 (0=absent, 4=most severe; Table 2). The sum of these scores was used as an overall histopathology score (minimum possible=0, maximum possible=80) for each badger.

We applied descriptive statistics for the initial categorization of injury (Tables 1 and 2). For statistical analysis, injury data were categorized into dichotomous groups. For gross pathology of the skin, an absence of injury and minor injuries were combined, as were severe injuries and cuts. For gross pathology of the subcutaneous tissue, an absence of injury and localized edema/petechial hemorrhage were combined, as were moderate and extensive edema/hemorrhage. For gross pathology of muscle, the three categories of muscle injury were combined

TABLE 1. Classification and definition of injuries to badgers because of capture in stopped restraints based on gross pathology: injuries recorded in 343 badgers (*Meles meles*) captured in stopped restraints in the Republic of Ireland, 2005–06.

Level	Classification	Definition	Thorax	Abdomen	Shoulder/ axilla	Total
Skin	No damage	No marking of skin because of restraint	7	8	0	15
	Hair loss/minor abrasion	Hair loss or minor denuding of epithelium but no cut	152	111	24	287
	Severe abrasion/ bruising	More severe epithelial denuding and bruising but no cut	14	17	3	34
	Cut	Any cut to the skin	3	3	1	7
Total skin			176	139	28	343
Subcutaneous tissue	No damage	No edema or hemorrhage	3	13	0	16
	Localized edema/ petechial hemorrhage	Edema± petechial hemorrhage extending <10 cm	115	104	1	220
	Moderate edema/ petechial hemorrhage	Edema±petechial hemorrhage extending 10–20 cm	54	19	15	88
	Extensive edema/ hemorrhage	Edema±hemorrhage extending >20 cm	4	3	12	19
Total subcutaneous tissue			176	139	28	343
Muscle	No damage	No visible damage	98	117	9	224
	Bruising	Slight muscle hemorrhage but no tearing of muscle	77	20	18	115
	Tearing/ hemorrhage	Visible tearing of muscle and severe hemorrhage	1	2	1	4
	Hematoma	Hematoma formation in muscle	0	0	0	0
Total muscle			176	139	28	343

(i.e., some injury vs. no injury). The histopathology scores were not normally distributed, so the median histopathology score (13; range, 0–47) was used to dichotomize the score.

Independent variables evaluated for associations with observed injuries included season, age, sex, body weight, chest girth, restraint girth, stop distance, and the position of the restraint on the body. The badgers' behavior, the location of the restraint in the environment, the topography of the local terrain, the physical condition of the restraint, the weather conditions, and the time period from dawn to euthanasia were recorded in the summer part of the study. The descriptive statistics we used included the Mann-Whitney test, to compare continuous variables between two groups, and the Kruskal-Wallis test, when there were three or more groups. We measured the degree of association between body weight and chest girth and restraint girth, and between chest girth and restraint girth using Pearson's correlation coefficient. All independent variables were tested for univariable associations with the four outcome variables (skin injury, subcutaneous tissue injury and muscle injury, or skin histopathology score) using simple logistic regression. Independent variables with <5% missing values and $P<0.2$ were included in an initial multiple logistic regression model for each of the four outcomes (this excluded all variables recorded only in the summer). The independent variables were further evaluated with backward elimination, with at $P<0.05$ (Dohoo et al., 2003). All statistical analyses were done using STATA SE 9 (StataCorp, College Station, Texas, USA).

RESULTS

The sex and age of the 343 badgers examined in this study; parameters including body weight, restraint girth, and chest girth; and the stop distance of the restraints, subdivided by age groups and season, are shown in Table 3. The proportion of males captured decreased with age in the winter ($P=0.001$) but not in the summer ($P=0.79$). We found a significant difference in body weight ($P<0.001$) and

TABLE 2. The histopathologic features examined and scores[a] applied to skin biopsies (n=327) of badgers (*Meles meles*) in the Republic of Ireland, 2005–06.

Skin	Histopathologic feature[b]	0	1	2	3	4
Epidermis	Erosion	194	81	21	23	8
	Epidermal necrosis	58	120	87	53	9
	Cleft formation	183	94	36	13	1
	Fibrin	274	42	10	1	0
	Proteinaceous material	290	28	7	2	0
	Cells, intact	247	60	14	5	1
	Cells, degenerate	262	48	12	5	0
Dermis	Dermal hemorrhage/hyperemia	9	157	122	37	2
	Dermal inflammation	17	173	92	41	4
	Dermal degeneration	46	139	108	34	0
	Superficial dermal blood vessels					
	Hyperemia	40	181	89	17	0
	Cuffing	152	158	16	1	0
	Cells, intact	152	163	12	0	0
	Cells, degenerate	313	12	2	0	0
	Periadnexal blood vessels					
	Hyperemia	27	187	102	11	0
	Cuffing	141	163	22	1	0
	Cells, intact	142	168	16	1	0
	Cells, degenerate	310	16	1	0	0
	Hair follicle/sebaceous gland degeneration	204	85	34	4	0
	Hemorrhage dermal-subcutaneous junction	260	47	17	3	0

[a] Histologic sections were examined independent of the gross pathologic findings, and each parameter was scored independently on scale of 0–4 (0=absent, 4=most severe).

[b] Erosion = loss of part or all of thickness of epidermis; necrosis = cell death; cleft formation = separation of epidermis and dermis; hyperemia = excess blood present; cuffing = white blood cells around a blood vessel; periadnexal = around hair follicle, sebaceous gland, or sweat gland

TABLE 3. The sex, age, weight (kg), restraint girth (cm), and chest girth (cm) recorded for young, adult, and old badgers (*Meles meles*; n=343) captured in stopped restraints, and the stop distance (cm) of the restraints after capture in winter and summer in the Republic of Ireland, 2005–06.

Variable	Age, median (range)			Total, median (range)
	Young (<18 mo)	Adult (18–60 mo)	Old (>60 mo)	
Winter				
Female	10	76	29	115
Male	16	61	6	83
Weight	8 (6–11)	10 (6–14)	11 (5–15)	10 (5–15)
Restraint girth	38 (34–49)	43 (27–52)	44.5 (33–51.5)	43 (27–52)
Chest girth	40 (34–49)	45 (33–53)	45 (33–51.5)	44.5 (33–53)
Stop distance	28.2 (27–30.5)	28.5 (24–31)	28.5 (25.5–30.6)	28.5 (24–31)
Summer				
Female	5	60	12	77
Male	5	55	8	68
Weight	7.1 (6–7.9)	8.6 (6.4–11)	8.5 (6.6–10.9)	8.5 (6–11)
Restraint girth	34 (28–36)	36 (27–50)	37.5 (33–42)	36 (27–50)
Chest girth	35 (29–37)	39 (34–51)	39 (33–43)	39 (29–51)
Stop distance	28 (27–29.5)	28 (26.5–30)	28 (25.5–29.5)	28 (25.5–30)

chest girth ($P=0.03$) between males and females in the summer but not in the winter ($P=0.23$ and $P=0.59$, respectively). The restraint girth ($P=0.17$) or stop distance ($P=0.60$) did not differ significantly between the sexes. We also found significant differences in body weight ($P<0.001$), chest girth ($P<0.001$), and restraint girth ($P<0.001$) among the age groups. Young animals had lower body weights ($P<0.001$) and significantly smaller chest girths ($P<0.001$) and restraint girths ($P=0.001$) than adult or old animals in both summer and winter, whereas adult animals had significantly lower body weights ($P=0.001$) than old animals in the winter but not in the summer. The stop distance of the restraint did not differ significantly among the age groups ($P=0.72$). We found that season had a significant effect on weight ($P<0.001$), chest girth ($P<0.001$), restraint girth ($P<0.001$), stop distance ($P<0.001$), and the position of the restraint on the body ($P<0.001$) but not on age ($P=0.08$) or sex ($P=0.36$). Both weight ($P<0.001$) and restraint girth ($P<0.001$) had a significant effect on the position of the restraint, but chest girth ($P=0.76$) did not. We found a strong and significant correlation between body weight and chest girth ($r=0.76$, $P<0.001$), between body weight and restraint girth ($r=0.72$, $P<0.001$), and between chest girth and restraint girth ($r=0.83$, $P<0.001$). Therefore, in the logistic regression model, we selected chest girth as the single indicator of body size because we believe it provided the most accurate measure among the three variables.

The 343 badgers were captured using 361 restraints: 327 badgers were captured with one restraint ($n=327$), 14 badgers with two restraints ($n=28$), and two badgers with three restraints ($n=6$). Data were collected separately for each restraint position, irrespective of whether there was one or more restraints at the position. There were seven badgers with two restraint positions (i.e., we recorded 350 separate restraint positions for 343 badgers). For analysis, we randomly selected one restraint position for each of the seven animals that had two restraint positions. Badgers were restrained at the thorax ($n=176$; 51.3%), abdomen ($n=139$; 40.5%), and diagonally across from the shoulder to the axilla ($n=28$; 8.2%). Two badgers caught at the thorax had their right forelimb caught in the restraint also; these animals were classified as caught at the thorax.

Gross pathology

There was an absence of injury or only minor skin abrasions in 302 (88%) cases. More serious classes of skin injury were observed in 41 (12%) cases, including severe skin abrasion and bruising in 34 cases (10%) and cuts in the skin in seven cases (2%; Table 1). The damage seen in those seven cases included a single cut of <1 cm long ($n=3$), a 4-cm-long cut ($n=1$), seven cuts 1–2 cm long along the line of the restraint ($n=1$), and two cases with severe cuts. Of the latter two, in one animal, the cut extended across the ventral abdomen for 15 cm and was 1 cm wide, whereas in the other animal, the cut extended for 15 cm from the right axilla to the point of the left shoulder and was 6 cm wide at its widest. There were no observable subcutaneous tissue injuries in 16 (4.7%) cases, whereas localized damage was seen in 220 (64.1%) cases, moderate damage in 88 (25.7%) cases, and extensive damage in 19 (5.5%) cases (Table 1). There was no observable muscle injury in 224 (65.3%) cases, with a further 115 (33.5%) cases and four (1.2%) cases showing slight or more serious muscle injury, respectively. No case of hematoma formation was observed (Table 1).

Additional capture injuries at sites other than where the restraint was located were observed in seven (2%) badgers. One badger had superficial skin abrasions on its chin, lips, one hind foot, and on the nail bed of one forefoot. This badger had multiple 1–2 cm cuts in the skin underlying the restraint. Two badgers each had a broken nail, and the remaining four had only superficial abrasions to nails, minor skin abrasions on the lower limbs, or superficial skin abrasion on a lip. Damage to teeth because of capture was not observed.

Additional observations

The time of euthanasia was recorded for 171 badgers (49.8%), with 41(20.7%) in the winter and 130 (89.6%) in the summer study, and from this, we calculated the time from dawn to euthanasia. The mean time from dawn to euthanasia in the summer (270 min; range, 53–436 min) was significantly ($P<0.001$) longer than the mean time in the winter (155 min; range, 30–335 min).

During the summer study, 68% ($n=95$) of badgers were captured on a path, 31.4% ($n=44$) were captured at the sett entrance, and one badger was captured with two restraints, one at the sett entrance and the other on a path. Most (56%; $n=80$) of restraints were laid on flat ground, with 43.7% ($n=62$) on a slope. Placement of restraints did not influence injury (Table 4). There was evidence of digging by the badger in 80.4% ($n=115$) of cases. Badger behavior on approach ranged from resting (54.5%, $n=79$) to thrashing (22.8%, $n=33$). The more active the badger was while in the restraint, the more likely that injury would occur. Overnight weather was dry on 61% ($n=86$) of occasions and wet on 39% ($n=55$) of occasions. Examination of the restraints following their use showed 38.3% ($n=54$) were smooth, whereas 61.7% ($n=87$) had some degree of twisting, unraveling, or fraying. Damaged restraints were associated with an increased risk of injury.

Ten badgers (2.9%) were captured with

TABLE 4. Odds ratios from univariable analysis of risk factors for injury to skin, subcutaneous tissue and muscle and skin histopathology of badgers (*Meles meles*) following capture in stopped restraints. Odds ratios <1 indicate a sparing factor; odds ratios >1 indicate a risk factor.

Variable	Odds ratio[a]			
	Skin injury	Subcutaneous tissue injury	Muscle injury	Skin histopathology
Season	5.1[b]	2.5[b]	2.5[b]	3.2[b]
Weight	0.6[b]	0.9[c]	0.8[b]	0.8[b]
Old vs. adult	0.3[c]	1.6[c]	2.1[b]	NS
Young vs. adult	2.1[c]	NS	1.7[c]	NS
Old vs. young[d]	0.1[b]	NS	NS	NS
Chest girth	0.8[b]	0.9[b]	0.9[b]	0.9[b]
Restraint girth	0.8[b]	0.9[b]	0.9[b]	0.9[b]
Stop distance	0.6[b]	0.8[c]	NS	NS
Thorax vs. abdomen	0.5[c]	2.4[b]	4.1[b]	NS
Shoulder/axilla vs. abdomen	NS	142.4[b]	11.1[b]	NS
Shoulder/axilla vs. thorax[d]	NS	58.6[b]	2.7[b]	NS
Daylight to euthanasia (hr)	1.6[b]	1.2[c]	1.3[b]	1.3[b]
Summer variables				
Pacing vs. resting	NS	0.5[c]	0.5[c]	NS
Running vs. resting	NS	7.4[c]	6[c]	NS
Damaged restraint	2.8[b]	2.0[c]	1.7[c]	2.4[b]
Terrain	NS	NS	NS	1.8[c]
Dry weather	NS	NS	0.5[b]	NS

[a] NS=nonsignificant, $P>0.2$.

[b] $P<0.05$.

[c] $P<0.2$.

[d] Postestimation testing.

more than one restraint at the same position on the body. These badgers had significantly higher odds of skin injury as assessed by gross pathology than those captured with a single restraint (odds ratio [OR]=6.4, P=0.007).

Histopathology

Of the skin biopsies examined (n=327), 54% showed minimal or no evidence of epidermal necrosis, 51% had minimal or no evidence of dermal hemorrhage, 58% had minimal or no evidence of dermal inflammation, and 57% had minimal or no evidence of dermal degeneration (Table 2).

There was a low, but significant, correlation between the histopathology scores and the gross pathology classification of the skin (r=0.34, P<0.001). The correlation was significant in the summer (r=0.47, P<0.001) but not in the winter (r=0.13, P=0.078).

Data analysis

For univariable and multivariable analysis, we confined the data set to those animals caught with a single restraint at one of the three positions on the body (n=334). Risk factors significant for injury following univariable analysis are listed in Table 4. The final logistic regression models for risk factors for injury based on histopathology of the skin and gross pathology of the skin, subcutaneous tissue, and muscle are shown in Table 5. Sex was not significant in any model. Season was a significant risk factor for histopathologic outcomes with higher scores in the summer. Smaller chest girths and smaller stop distances were significant risk factors for skin injury. Season (capture in the summer) and the position of the restraint on the body were significant risk factors for subcutaneous tissue injury; the odds of injury were significantly higher when the restraint lay diagonally from the shoulder to axilla (OR=182.1) and was significantly higher when the restraint was at the thorax (OR=3.7) compared with at the abdomen. Injury observed when the restraint was at the shoulder/axilla was significantly higher (OR=49.2) than when the restraint was at

TABLE 5. Odds ratios from multivariable logistic regression models for risk factors for badger (*Meles meles*) injury because of capture in stopped restraints, based on gross pathology at the level of the skin, subcutaneous tissue and muscle, and skin histopathology.

Histopathology	Odds ratio	Coefficient	SE	z	$P>\|z\|$	95% CI[a]	
Skin lesion							
Summer	3.2	1.2	0.24	4.86	0.00	0.7	1.6
Gross pathology skin injury							
Chest girth	0.8	−0.2	0.05	−3.85	0.00	−0.3	−0.1
Stop distance	0.6	−0.5	0.21	−2.28	0.02	−0.9	−0.1
Subcutaneous injury							
Thorax vs. abdomen	3.7	1.3	0.3	4.13	0.00	0.7	1.9
Shoulder/axilla vs. abdomen	182.1	5.2	1.1	4.91	0.00	3.1	7.3
Shoulder/axilla vs. thorax[b]	49.2	3.9	1.0	3.75	0.00	1.9	5.9
Summer	3.6	1.3	0.3	4.27	0.00	0.7	1.9
Muscle injury							
Thorax vs. abdomen	7.2	2.0	0.3	5.95	0.00	1.3	2.6
Shoulder/axilla vs. abdomen	14.4	2.7	0.5	5.26	0.00	1.7	3.7
Shoulder/axilla vs. thorax[b]	2.0	0.7	0.5	1.48	0.14	−0.2	1.6
Old vs. adult	2.0	0.7	0.3	2.02	0.04	0.02	1.4
Young vs. adult	3.0	1.1	0.4	2.43	0.02	0.2	2.0
Old vs. young[b]	0.7	−0.4	0.5	−0.78	0.44	−1.4	0.6
Summer	5.1	1.6	0.3	5.4	0.00	1.0	2.2

[a] CI = confidence interval.

[b] Postestimation testing.

the thorax. Season (capture in the summer), age, and the position of the restraint on the body were significant risk factors for muscle injury. Both young (OR=3.0) and old (OR=2.0) animals had significantly higher odds of muscle injury than adult animals, whereas the odds ratio for muscle injury was significantly higher when the restraint lay diagonally from shoulder to axilla (OR=14.4) or at the thorax (OR=7.2) compared with when it was at the abdomen. We found no interaction between season and the position of the restraint on the animal for either subcutaneous ($P=0.11$) or muscle injuries ($P=0.28$). The effect of age depended on neither season ($P=0.40$) nor the position of the restraint ($P=0.57$) for muscle injury. Although chest girth was not significant in the final models for subcutaneous or muscle injury, there was no interaction between it and season with respect to degree of injury.

DISCUSSION

In this study, physical injuries to badgers attributable to capture in stopped restraints were classified according to the severity of the injuries. The majority of badgers suffered minimal injury as a result of capture by this method. In the small number of cases where more serious injury was observed, multivariable analysis identified a number of factors that may have influenced the degree of injury sustained: These included season, age, chest girth (highly correlated to weight and restraint girth), the position of the restraint on the body, and the stop distance of the restraint.

Season was a general predictor of injury at all three levels (skin, subcutaneous tissue, and muscle), with less serious injuries observed in the winter than the summer. The effect of season on injury did not depend on the position of the restraint on the animal or on age. When we included season, age, and chest girth in the same models, we found that only season and/or age were significant factors associated with subcutaneous or muscle injury. This indicated that chest girth effects on these injuries were confounded by season and/or age. As expected, there was a strong correlation between body weight, chest girth, and restraint girth, with lower body weights correlated with smaller chest girths and smaller restraint girths. Season had a significant effect on weight, chest girth, and restraint girth. It is well established that the body weights of badgers fluctuate throughout the seasons, with badgers being heaviest in the late autumn and early winter, primarily because of the deposition of an increased subcutaneous fat layer in preparation for the winter. Noting that chest girth was statistically significant only for skin injury, we surmise that lighter, smaller badgers have less subcutaneous fat than heavier, larger badgers and are more prone to restraint injury because subcutaneous fat may provide a degree of protection. The absence of the chest girth effect on subcutaneous and muscle injury suggests that the seasonal influence has effects on attributes other than chest girth measurements, which affect the degree of injury in restrained badgers.

The position of the restraint on the body had a significant effect on the degree of subcutaneous and muscle injuries, with less-severe injuries seen when the animal was caught at the abdomen compared with when the restraint was at the thorax or diagonally across from the shoulder to the axilla. This may, in part, be explained by the adaptability of the abdominal wall to accommodate compressive forces, in contrast to the more rigid nature of the thoracic wall and shoulders. Badgers caught at the shoulder-axilla had the highest odds of serious subcutaneous injury and commonly had extensive edema and hemorrhage, which extended down the associated forelimb. This was probably due to pressure on the axillary blood vessels and lymphatics from the restraint, resulting in the development of dependent edema.

The observation that the stop distance of the restraint constituted a significant risk factor for skin injury in our multivariable analyses was unexpected. Although restraints are designed with a stop distance of 28 cm, we found a range of 24–31 cm. However, because the restraint girth (range, 27–52 cm) of the captured badgers was seldom smaller than the stop distance, the stop would not have come into play when capturing most badgers. Nevertheless, because smaller stop distances were a significant risk factor for skin injury, there may be a benefit from increasing the stop distance and a need for quality control of the manufacture of the restraints to ensure they comply with the specifications for the product.

The length of time a badger is held in a restraint may be a predictor of injury. However, this time period is difficult to measure accurately, and we used the time period between dawn and euthanasia, while acknowledging its limitations, as a surrogate measure. In our study, the maximum period of time a badger was restrained would not have exceeded 18 hr. Studies of arctic foxes (*Alopex lagopus*) have shown that the longer the period of time an animal is caught in a leg-hold trap, the more serious the injuries suffered (Proulx et al., 1994). In contrast, a study in the United Kingdom on the use of cage traps, which also used the time from dawn to euthanasia as a surrogate variable for the duration of capture, reported that the time spent in the trap was not associated with the degree of trap-related injuries (Woodroffe et al., 2005). Further studies to include several successive seasons may be warranted to fully evaluate the relationship between restraint injuries and time in restraint. It is our recommendation that, during culling operations, restraints are checked as early in the morning as possible.

Our assessment of the role of placement of restraints, the behavior of badgers in the restraint, and the condition of the restraint was limited because of the small numbers of badgers captured in the summer study. Nevertheless, based on our findings, we advise the continued sourcing of high-quality restraints that resist fraying and the placement of restraints in the environment to minimize the risk of capture with multiple restraints.

In the Republic of Ireland, restraints have been used routinely as a means of capturing badgers for culling (DAFF, 1996). Restraints have the advantages of being relatively inexpensive, lightweight, easily transported, and easily positioned, and they do not require bait. As a means of monitoring skin injuries on a continuing basis, gross pathology would be easier to apply than histopathology. However, the correlation between histopathology and gross pathology for skin injuries in this study was not strong. This may, in part, be explained by the difference in the samples examined. The gross pathology was based on skin injury along the entire circumference of the badger at the level of the restraint, whereas the skin biopsy was only 1–2 cm wide and taken from a single site under the restraint. The biopsy may not, therefore, have always been representative of the overall restraint injury.

A previous study in the United Kingdom examined injuries sustained by badgers captured in cage traps (Woodroffe et al., 2005) and found that 88% of badgers exhibited no detectable injury. However, the two studies are not directly comparable because of differences in methodology and analysis. In our study, we scored injury at the site of the restraint based on gross pathology as well as histopathology, used an objective classification scheme for gross lesions, and recorded injuries to other areas of the body. In contrast, the UK study looked at superficial injuries and used a modification of the trauma scale described in the International Organization for Standardization (ISO) 10990-5 (ISO, 1999) report. The trauma scale and evaluation was developed as part of an overall performance test of traps used to restrain land mammals and included traps based on striking and clamping forces. Therefore, that generic scale covered a very broad range of trap-related injuries, from claw loss to death, and offered poor differentiation of degrees of injury at a single site.

Our study showed that the severity of physical injuries sustained because of capture with stopped restraints was low. However, physical injuries are just one aspect of the welfare of badgers captured with stopped restraints. We have not attempted to quantify the pain and stress that may be associated with this method of capture. Badgers are wild animals and there is always a risk that when captured some may struggle leading to serious physical injuries. We recognize that minimizing injuries to captured badgers is paramount from a welfare point of view. The ongoing monitoring of physical injuries to badgers subjected to capture in stopped restraints may enable the identification of additional risk factors that may help to limit injuries in captured badgers.

ACKNOWLEDGMENTS

This study was funded by the Department of Agriculture, Fisheries and Food. We wish to thank the veterinary, technical, and field staff from the participating District Veterinary Offices, and U. Fogarty and staff at the Irish Equine Center, for their cooperation with this study.

LITERATURE CITED

CHEESEMAN, C. L., AND P. J. MALLINSON. 1979. Radio tracking in the study of bovine tuberculosis in badgers. *In* A handbook on biotelemetry and radio tracking, C. I. Amlaner and D. W. Macdonald (eds.). Pergamon Press, Oxford, UK. pp. 646–656.

[DAFF] DEPARTMENT OF AGRICULTURE, FOOD AND FORESTRY. 1996. Badger manual. Government of Ireland, Dublin, Ireland.

DOHOO, I., W. MARTIN, AND H. STRYHN. 2003. Veterinary epidemiologic research. AVC Inc., Charlottetown, Prince Edward Island, Canada, 706 pp.

EVES, J. A. 1999. Impact of badger removal on bovine tuberculosis in East County Offaly. Irish Veterinary Journal 52: 199–203.

GORMLEY, E., AND J. D. COLLINS. 2000. The development of wildlife control strategies for eradication of tuberculosis in cattle in Ireland. Tubercle and Lung Disease 80: 229–36.

GRIFFIN, J. M., D. H. WILLIAMS, G. E. KELLY, T. A. CLEGG, I. O'BOYLE, J. D. COLLINS, AND S. J. MORE. 2005. The impact of badger removal on the control of tuberculosis in cattle herds in Ireland. Preventive Veterinary Medicine 67: 237–266.

[ISO] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 1999. Animal (mammal) traps, Part 5: Methods for testing restraining traps—ISO Publication 10990-5. ISO, Geneva, Switzerland.

O'MAIRTIN, D., D. H. WILLIAMS, J. M. GRIFFIN, L. A. DOLAN, AND J. A. EVES. 1998. The effect of a badger removal programme on the incidence of tuberculosis in an Irish cattle population. Preventive Veterinary Medicine 34: 47–56.

PROULX, G., I. M. PAWLINA, D. K. ONDERKA, M. J. BADRY, AND K. SEIDEL. 1994. Field evaluation of the number 1 1/2 steel-jawed leghold and the Sauvageau 2001-8 traps to humanely capture aortic fox. Wildlife Society Bulletin 22: 179–183.

SOUTHEY, A. K., D. P. SLEEMAN, J. PRENDERGAST, R. F. O'SULLIVAN, AND M. F. MULCAHY. 2001. Use of biomarkers to assess the feasibility of delivering a vaccine to badgers (*Meles meles*). Journal of Zoology 253: 133–139.

WOODROFFE, R., F. J. BOURNE, D. R. COX, C. A. DONNELLY, G. GETTINBY, J. P. MCINERNEY, AND W. I. MORRISON. 2005. Welfare of badgers (*Meles meles*) subjected to culling: patterns of trap-related injury. Animal Welfare 14: 11–17.

Received for publication 1 February 2008.