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Inventory of wildlife use of mortality pits as feeding sites: implications of pathogen exposure

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Abstract: To better understand the use of mortality pits by wildlife and possible pathogen dissemination from the resulting wildlife contact in these areas, we used 8 camera traps on 4 mortality pits in Colorado from June to December 2014 to create a species inventory and establish use estimates for those species. We observed 43 species visiting (in or near) the mortality pits during 1,168 total camera trap days. Of these, 24 species directly interacted with the mortality pits or carcasses contained within them. The most common visitors to mortality pits were raccoons (*Procyon lotor*), coyotes (*Canis latrans*), domestic dogs (*Canis lupus familiaris*), mule deer (*Odocoileus hemionus*), bald eagles (*Haliaeetus leucocephalus*), black-billed magpies (*Pica hudsonia*), corvid species (i.e., American crows [*Corvus brachyrhynchos*] or common ravens [*Corvus corax*]), great blue herons (*Ardea herodias*), house sparrows (*Passer domesticus*), and turkey vultures (*Cathartes aura*). Mammals were often solitary visitors to mortality pits, while birds often visited mortality pits in mixed flocks of 2 to 5 species, putting them at a higher risk of interspecific pathogen spread. Our findings indicate that many animals come into direct and indirect contact with interspecific and conspecific species at mortality pits.

Key words: camera trap, mortality pit, wildlife disease, wildlife feeding

Anthropogenic manipulations of wildlife habitat can have considerable effects on the epidemiology of infectious diseases (Daszak et al. 2001, Brearley et al. 2013). This may be particularly important when people change wildlife feeding patterns through the use of feeding sites such as garbage dumps, livestock feed, and mortality pits because animals come into contact more frequently and spend more time in these common-use areas (Campbell et al. 2013, Sorensen et al. 2014). One type of artificial feeding site utilized by wildlife is mortality pits located on animal rearing facilities and concentrated animal feeding operations for carcass disposal. Carcasses in these pits can be buried or mixed with other materials for composting. There is a risk of wildlife introducing, propagating, or disseminating pathogens when animals extensively use or congregate at these sites (Daszak et al. 2000, Miller et al. 2013, Clark et al. 2014).

Carcasses may be deposited in mortality pits for various reasons, such as animals euthanized for health reasons, euthanized pest species, road kill, or animals (domestic and wildlife) that died of unknown causes. In many instances, the disease status of a carcass of concern is unknown. However, an animal that died as a result of infection may contain large numbers of pathogenic agents, dependent on how long the carcass has been decomposing and the stability of the agent in question (Wobeser 2006). Therefore, if a pathogenic agent is viable in a carcass, transmission or spread of the pathogen could occur as a result of animals scavenging on the carcass (Michel et al. 2006, Anderson et al. 2007, Fischer et al. 2013). While the use of human modified feeding sites (e.g., dumps, stored food, etc.) by wildlife has been documented (Daniels et al. 2003, Peirce and Van

Daele 2006, Robb et al. 2008), use of mortality pits by wildlife has yet to be quantified.

The objectives of this study were to identify animals that visited selected mortality pits using passive infrared camera traps and to determine rates of visitation of the most common wildlife species. Furthermore, the implications of pathogen transmission at these anthropogenically modified sites are discussed.

Methods

Study sites

This study was conducted at 4 mortality pit sites in Larimer and Weld counties, Colorado, USA from June 2014 to December 2014. Three of these sites were located in Larimer County (A, B, and C) and 1 site in Weld County (D). Sites A and C were in a semi-rural area in close proximity to houses, farms, and crop fields. Site C was in close proximity to a reservoir and Cache la Poudre River. Site B was located in a flat open meadow surrounded by steep pine and spruce forested mountains and close to the Cache la Poudre River and Colorado Highway 14. Site D was in a rural, dry, short-grass prairie area where there were only 7 houses within 1 km of the site. These sites were chosen for the varied habitat, and the type of carrion in each pit ranging from fish eggs and fish to birds and large mammals. Carrion at sites A, B, and C primarily consisted of fish products. The carrion at site D was primarily raccoon (*Procyon lotor*), mule deer (*Odocoileus hemionus*), and elk (*Cervus canadensis*) from road kill. Carrion was added to sites A and B almost daily and to sites C and D approximately 1–4 times per month.

Cameras

We placed 2 Bushnell® Trophy Cam™ HD trail cameras at each site. The first camera was set to take 2 infrared-activated motion-capture photos for each triggering event after a 10-second delay between events and to be active 24 hours per day. According to the manufacturer, the response time delay between when motion was sensed and a photo was taken was 0.6 seconds. The second camera was originally programmed to take 1 time-lapse photo every minute from 1600 to 1200 daily, but after 4 weeks this was adjusted to 1 photo every 5 minutes due to high rate of camera failure. We selected the timeframe of 1600 to 1200 to avoid the hottest part of the day when cameras were prone to overheating and failing. Each camera was set to stamp the date and time on each photo taken. Cameras were placed 1–5 m from the center of the mortality pit on vertical t-posts at a height of 0.5 m. Memory cards and rechargeable batteries were changed weekly in summer and monthly in autumn.

Analysis

All photos containing animals were recorded to include site, date, time, event number, and species. This information was organized by location to determine the total days visited and number of events (when an animal triggered the camera) by species for each location and camera type. The species were placed into 2 broad categories depending on behavior. Species that consumed or otherwise directly interacted with carcasses by smelling or touching were classified as primary visitors. Species that did not directly interact with carcasses were classified as incidental visitors. Only the top 10 primary species with the most trap-day observations were selected for further analysis (>200 events). From this species list, a mean number of events per visited day was determined for each species and camera type. To quantify animal visitation for both camera types, we calculated visitation rates as the number of days a species event was recorded at a site divided by the trap-days for that site.

Results

Over the course of the study with both camera configurations, we observed 43 species visiting the mortality pits or the area immediately around the mortality pits during 1,168 total camera trap-days (Table 1). Camera trap-days were defined as days when the camera worked continuously without failure. The motion capture cameras captured 30 species while the time-lapse cameras captured all 43 species. Of these, 19 species were classified as incidental visitors or visitors that did not interact with the mortality pit, its contents, or carcasses within. However, the other 24 species directly interacted with carcasses within the mortality pits. Raccoons, coyotes (*Canis latrans*), domestic dogs (*Canis lupus familiaris*), mule deer, bald eagles (*Haliaeetus leucocephalus*), black-billed magpies (*Pica hudsonia*), American

Table 1. Species encountered at mortality pits from June–December 2014 in Larimer and Weld counties, Colorado, USA. Species that did not directly interact with carcasses or mortality pit sites were classified as incidental visitors, whereas species that were observed interacting with carcasses or mortality pits were classified as primary visitors. Events are defined as 2 photos of an animal for the motion-capture cameras, or 1 photo of an animal captured by the time-lapse cameras.

Mammals	Events	Birds	Events
Black bear (*Ursus americanus*)	12	American kestrel (*Falco sparverius*)	32
Black-tailed jackrabbit (*Lepus californicus*)	6	American robin (*Turdus migratorius*)*	34
Chipmunk (*Tamias* spp.)	19	Bald eagle (*Haliaeetus leucocephalus*)	921
Raccoon (*Procyon lotor*)	1,329	Black-billed magpie (*Pica hudsonia*)	8,346
Cottontail (*Sylvilagus* spp.)	93	Blue jay (*Cyanocitta cristata*)*	1
Coyote (*Canis latrans*)	2,079	Brewer's blackbird (*Euphagus carolinus*)*	1
Domestic cat	23	Bullock's oriole (*Icterus bullockii*)*	1
Domestic dog	394	Canada goose (*Branta canadensis*)*	11
Domestic horse*	1,164	Cliff swallow (*Petrochelidon pyrrhonota*)*	1
Moose (*Alces alces*)*	5	American crow or common raven (*Corvus* spp.)	6,789
Mule deer (*Odocoileus hemionus*)	212	Dark-eyed junco (*Junco hyemalis*)*	41
Red fox (*Vulpes vulpes*)	9	European starling (*Sturnus vulgaris*)	13
Unidentified small mammals	204	Golden eagle (*Aquila chrysaetos*)	20
White-tailed deer (*Odocoileus virginianus*)	110	Great blue heron (*Ardea herodias*)	1,255
Wyoming ground squirrel (*Urocitellus elegans*)*	103	Green-tailed towhee (*Pipilo chlorurus*)*	2
		House finch (*Carpodacus mexicanus*)*	8
		House sparrow (*Passer domesticus*)	408
		Lesser goldfinch (*Carduelis psaltria*)	2
		Loggerhead shrike (*Lanius ludovicianus*)	6
		Mourning dove (*Zenaida macraura*)	2
		Northern flicker (*Colaptes auratus*)*	1
		Owl (species unknown)*	7
		Sparrow (species unknown)*	129
		Turkey vulture (*Cathartes aura*)	728
		Tyrant flycatcher (Tyrannidae)*	6
		Unidentified birds*	1
		Western kingbird (*Tyrannus verticalis*)*	172
		Western meadowlark (*Sturnella neglecta*)*	13

*An incidental visitor is one that was never observed interacting (eating, standing on, or otherwise manipulating) with a carcass or was never inside a mortality pit.

Table 2. Events and frequency of visitation by site for the top 10 visiting species of mortality pits from June–December 2014 in Larimer and Weld counties, Colorado, USA. Events are defined as 2 photos of an animal for the motion-capture cameras, or 1 photo of an animal captured by the time-lapse cameras. Days visited are the days in which there was ≥1 event. Events per day was the average number of events per days visited. The visitation rate was the days visited divided by trap-days. For each animal, the first row is motion capture and the second row is time lapse.

Animal	Events	Days visited	Events per day	Visitation rate
Site A				
Coyote	695	39	17.82	0.28
	163	34	4.79	0.23
Dog	47	13	3.62	0.09
	16	9	1.78	0.06
House sparrow	30	7	4.29	0.05
	378	34	11.12	0.23
Black-billed magpie	35	9	3.89	0.06
	96	27	3.56	0.18
Mule deer	90	17	5.29	0.12
	13	10	1.30	0.07
Raccoon	448	41	10.93	0.29
	395	37	10.68	0.25
Trap-days		141		
		149		
Site B				
Bald eagle	701	42	16.69	0.27
	220	30	7.33	0.20
Coyote	658	40	16.45	0.26
	228	36	6.33	0.24
American crow or common raven	4,322	66	65.48	0.43
	2,467	66	37.38	0.45
Black-billed magpie	4,153	70	59.33	0.45
	3,326	80	41.58	0.54
Mule deer	71	10	7.10	0.06
	9	5	1.80	0.03
Turkey vulture	515	10	51.50	0.06
	213	8	26.63	0.05
Trap-days		154		
		147		
Site C				
Coyote	213	32	6.66	0.21
	89	32	2.78	0.23
Dog	2	1	2.00	0.01
	0	0	0	0
Black-billed magpie	193	22	8.77	0.15
	347	35	9.91	0.25
Mule deer	20	4	5.00	0.03
	6	2	3.00	0.01
Raccoon	330	58	5.69	0.39
	155	50	3.10	0.35
Great blue heron	763	78	9.78	0.52
	492	48	10.25	0.34
Trap-days		149		
		142		
Site D				
Coyote	13	6	2.17	0.05
	20	11	1.82	0.07
Dog	137	12	11.42	0.09
	192	12	16.00	0.08
Black-billed magpie	24	11	2.18	0.08
	172	29	5.93	0.18
Mule deer	-	-	-	-
	3	2	1.50	0.01
Raccoon	-	-	-	-
	1	1	1.00	0.01
Trap-days		130		
		158		

Table 2 continued in next column.

Figure 1. Mule deer inspecting a mule deer carcass recently placed in the mortality pit site B.

crows (*Corvus brachyrhynchos*) or common ravens (*Corvus corax*), great blue herons (*Ardea herodias*), house sparrows (*Passer domesticus*), and turkey vultures (*Cathartes aura*) were the species that interacted with mortality pits and carcasses most often and were chosen for additional analysis.

Bald eagles, American crows, common ravens, and turkey vultures were only observed at site B. Vultures were only observed from July 1–29. Herons were only observed at site C between June 23 and September 23, and house sparrows were only observed at site A from June 23 to August 23. Coyotes, magpies, and mule deer were observed at all 4 sites. Raccoons and dogs were observed at sites A, C, and D.

Coyotes were seen at all 4 sites but were only observed at night and in the early morning. In addition, coyotes were almost always the sole species occupying the site when using the mortality pits. Coyotes were one of the few species that could often be individually identified by their fur color patterns, features, and overall body condition. The same individuals consistently visited their respective sites. One individual at site A, which was identified by only having one eye, was the only coyote to visit the site. It visited 39 out of 141 trap-days and spent much time at the site (17 average events per visited day; Table 2). Sites B and C showed similar visitation rates by coyotes but with 2 and 4 individuals using each site, respectively. Similarly, raccoons were only periodically observed at night and were often in family groups that would occupy the site for considerable time (Table 2). Coyotes and raccoons were only rarely observed together at a site; more often their presence was followed or preceded by the other species by only minutes. For example, in 1 instance a coyote was present at site C at 2124 hours and then a raccoon appeared at 2142 hours. The coyote reappeared 3 hours later at 0141 hours, and a raccoon (unknown if it is the same individual) appeared later at 0427 hours.

Mule deer also visited the sites alone or in small groups. Only once was a mule deer observed in close contact with another species, when a single mule deer was observed with a coyote. While mule deer were not observed consuming any of the carcasses or parts, they would often feed on the vegetation around carcasses or would inspect carcasses, which is consistent with other studies of deer (Jennelle et al. 2009). Deer inspecting carcasses were especially pronounced when a fresh deer or elk carcass was added to a mortality pit, as deer were often among the first visitors to the area to inspect the carcass (Figure 1). Furthermore, great blue herons were common visitors to site C from June to September and often came into close contact with Canada geese (*Branta canadensis*) and black-billed magpies. The high visitation of great blue herons was likely due to the large amount of fish carrion present at that site as well as the close proximity of the mortality pit to riparian areas. House sparrows were commonly observed interacting with carrion at site A, but from the photos collected in this study, it was unclear if they were consuming small bits of the carcasses or the insects in and around the carcasses. This activity in house sparrows was only observed from early July to late August and may have been associated with chick rearing when supplementary protein, especially that from insects, is delivered to nestlings (Vincent 2005).

While black bears (*Ursus americanus*), black-tailed jackrabbits (*Lepus californicus*), cottontail rabbits (*Sylvilagus* spp.), feral cats (*Felis catus*), red foxes (*Vulpes vulpes*), small mammals, white-tailed deer (*Odocoileus virginianus*), American kestrels (*Falco sparverius*), European starlings (*Sturnus vulgaris*), lesser goldfinches (*Carduelis psaltria*), loggerhead shrikes (*Lanius ludovicianus*), and mourning doves (*Zenaida macraura*) visited the sites and interacted with or consumed carcasses, their presence was rare and visitation to mortality pits may not indicate attraction to carrion by these species.

The highest visitation rate recorded was for black-billed magpies, which visited on 80 days (54%) of the total camera-trap days at site B (Table 2). Similarly, great blue herons (site C) and American crows or common ravens (site B) visited sites nearly as often at 52% and 45% of the trap-days, respectively. Bald eagles visited site B on 27% of the trap-days, house sparrows visited site A on 23% of the trap-days, and turkey vultures visited site B on only 6% of the trap-days. Of the mammals we observed, raccoons and coyotes had the highest visitation rates at 39% (site C) and 28% (site B) of the trap-days, respectively, while mule deer and domestic dogs had relatively low visitation rates at 12% (site A) and 9% (site D) of total trap-days, respectively.

Discussion

There are many reasons that mortality pits may influence pathogen exposure and spread in wildlife. Mortality pits could bring animals together and enhance pathogen spread via close contact. Some pathogens may also be contracted when a scavenger consumes parts of a carcass or when animals ingest insects feeding on the carcass. Herbivores may also be attracted to sites containing carcasses because of the pulse of nutrients that improve soil and vegetation growth, which may lead to feeding on areas previously contaminated with pathogens.

Our observations from the mortality pits indicated that close interspecific and intraspecific contact between animals may be of concern when considering pathogen spread. We observed groups of black-billed magpies and other corvids visit mortality pits frequently, and the presence of 1 species was almost always followed by the other. The presence of bald eagles and turkey vultures was also accompanied by black-billed magpies and American crows or common ravens (Figure 2). There may have been many factors influencing the composition and existence of interspecific flocks of birds at this site, including the potential detection of feeding cues from other species. This pattern has been observed in Old World vultures (Piper 2005, Cortés-Avizanda et al. 2014, Kane et al. 2014) and marine birds (Hoffman et al. 1981, Anguita and Simeone 2015). When birds concentrate in small areas, there is potential for pathogens to spread through direct contact with other individuals, through feces, or through fomites. Avian pox virus, for example, can be disseminated in a similar setting where many birds are gathered around a common feeding area and the virus is spread through contact with contaminated perches (van Riper and Forrester 2007). Other pathogens, such as avian paratuberculosis (*Mycobaterium avium*) and avian influenza virus, can be spread through contact with infected feces, resources contaminated by feces (i.e., water), and scavenging of an infected animal (Biet et al. 2005, Reperant et al. 2008, VanDalen et al. 2010, Root et al. 2014). Mammal carcasses added to mortality pits or mammals visiting the pits could also spread parasites that cause mange or harbor *Yersinia pestis* (the etiologic agent of plague) or *Francisella tularensis* (the etiologic agent of tularemia). Distemper virus and hantaviruses may also pose a risk for visiting animals (by the former) and people (by the latter) as these pathogens can be spread

Figure 2. Mixed flock of bald eagles, American crows or common ravens, and black-billed magpies at the mortality pit site B.

through direct contact, contact with urine, or aerosolized urine (Deem et al. 2000, Kallio et al. 2006). Just as direct contact with other animals or their waste can be a problem at mortality pits, the ingestion of carcasses may pose a risk of pathogen spread in visiting wildlife.

Another risk pathway in which mortality pits may influence pathogen spread is through direct ingestion of a carcass. For example, bald eagles were thought to have been infected with West Nile virus after consuming infected eared grebes (*Podiceps nigricollis*; Ip et al. 2014). Similarly, red foxes and striped skunks (*Mephitis mephitis*) contracted rabies after being fed infected mouse carcasses in a laboratory setting (Ramsden and Johnston 1975), and red foxes exhibited mild illness following consumption of chick carcasses infected with a highly pathogenic avian influenza virus in a laboratory (Reperant et al. 2008).

Many carnivorous species practice scavenging to some degree (DeVault et al. 2003). It is also important to note that although we observed herbivorous and/or granivorous species (rabbits, small mammals, and white-tailed deer) interacting with carcasses, they likely used mortality pits to a lesser degree, possibly for supplemental nutrient intake. This may indicate another risk pathway for these species to contract pathogens. Many ruminants have been observed consuming tissue and or chewing on bones (osteophagia), which is thought to be a response to nutrient deficiency (Cáceres et al. 2011, Walter et al. 2015). This puts them at risk of contracting many pathogens, such as those that cause botulism, chronic wasting disease (CWD), and brucellosis. Of these, botulism is of particular interest because it can affect many species that might ingest the toxin from a carcass or insects that fed on an infected carcass. Waterfowl species are particularly prone to botulism as they will eat maggots that have concentrated the toxin after feeding on an infected carcass (Rocke and Bollinger 2007). Scavenging red-tailed hawks (*Buteo jamaicensis*) have also died from botulism, likely as a result of feeding on chicken carcasses in a mortality pit (Rocke and Bollinger 2007). Goats have contracted botulism when practicing osteophagia (Riet-Correa et al. 2012). In a mortality pit setting, insects capable of transmitting pathogens may be attracted to or dispersed by carcasses or by animals visiting the carcasses. This suggests that insectivorous, carnivorous, and herbivorous species feeding at a mortality pit site can come into contact with pathogens even when not directly feeding on the broadcasting carcass. Consequently, species not commonly associated with scavenging are at risk of pathogen spread not only inside a mortality pit, but also in the area around the mortality pit where insects have disseminated from a carcass.

Herbivores also fed in and around the mortality pits in areas that could have been exposed to carcasses and their resultant pathogens, toxins, or insects. As carcasses decay, they can release a pulse of nutrients that increase vegetation growth, which attracts herbivores and could expose them to environmentally transmitted pathogens (Turner et al. 2014). This may put feeding herbivores at risk of contracting the etiologic agents causing CWD, brucellosis, or anthrax without coming into contact with or directly interacting with a carcass. For example, Miller et al. (2004) found that mule deer contracted CWD after being placed in pens that had CWD-positive deer carcasses decomposing 1.8 years prior. *Brucella abortus* is commonly contracted in elk and bison (*Bison bison*) from contact with aborted fetuses and grazing on contaminated plants around an abortion site (Dobson and Meagher 1996), and aborted fetusus and afterbirth are often disposed of in mortality pits. Turner et al. (2014) found that herbivores are attracted to vegetation growing in areas where carcasses with *Bacillus anthracis* were decaying, potentially exposing them to the bacteria. All of the aforementioned scenarios are dependent on viable pathogens remaining infectious for a period of time in semi-natural environments.

Another risk for wildlife is the ingestion of drugs (used to treat or euthanize animals), pesticides, or lead at mortality pit sites. Langelier (1993) found that bald eagles that ingested the flesh of a cow euthanized with sodium pentobarbital showed signs ranging from sedation to unconsciousness, and 5 of 29 eagles died as a result. Secondary exposure of rodenticides to predators and scavengers has also been documented to be widespread (Howald et al. 1999, Thomas et al. 2011). The ingestion of lead from bullet fragments could result in lead exposure of many avian scavengers (Fisher et al. 2006, Grund et al. 2010, Cruz-Martinez et al. 2012), including some observed in this study (e.g., American kestrel, bald eagles, dark-eyed junco [*Junco hyemalis*], golden eagles, mourning dove, owls, and turkey vultures).

Congregations of wildlife may support pathogen transmission in some instances. For example, we observed that many species including mule deer, raccoons, and cottontail rabbits congregated in small numbers or family groups at the mortality pit sites. Sorensen et al. (2014) indicated that supplemental feeding influences diseases in cervids, but it is not well understood how pathogens may affect small or less observable species associated with supplemental feeding. The mortality pits attracted birds in large numbers. This increased density over a small area could potentially result in higher pathogen transmission through direct contact between individuals or their excretions that are concentrated at the site, fomite contact (soil, vegetation, anthropogenic structures), or increased contact with potential insect vectors such as ticks, fleas, flies, and other insects associated with decomposition.

Overall pathogen exposure risk associated with mortality pits may be difficult to quantify due to the large variation in pathogen survivability in carcasses and environmental conditions. Xu et al. (2009) found that *Escherichia coli* and Newcastle disease virus degraded quickly under composting conditions, but *Campylobacter jejuni* remained viable for ≤84 days. Similarly, *Brucella abortus* can survive in the environment for ≤81 days (Aune et al. 2012). Some pathogens can remain viable in the environment for much longer. *Mycobacterium avium* has been documented to survive ≤55 weeks and is resistant to composting (Whittington et al. 2004, Tkachuk et al. 2013). Avian pox virus can remain viable in scabs for extended periods, and *Bacillus anthracis* or *Clostridium botulinum* spores can remain viable for many years (Wobeser 1997, van Riper and Forrester 2007, Sinclair et al. 2008). Additionally, chronic wasting disease prions can be readily found among carcasses and can remain viable for years in the environment (Miller et al. 2004). However, some viruses, such as avian influenza virus, may only remain viable for hours to days, depending on many environmental factors (Weber and Stilianakis 2008). Canine distemper virus can survive ≤15 days in cold temperatures (Deem et al. 2000). Viable rabies virus has been detected in carcasses ≤18 days after death in cold environments but only 3 days in warmer situations (McElhinney et al. 2014). Similarly, Puumala virus (a hantavirus) have been shown to survive ≤18 days in cold temperatures (Kallio et al. 2006).

Management implications

Animals in indirect contact with mortality pits soon after an infected carcass is deposited may be at a higher risk of overall pathogen exposure; however, animals coming into indirect contact over days, months, or years after an infected carcass is deposited may still be at risk from certain pathogens. Considering the mortality pits we observed were frequently visited by many different individuals daily, risks of pathogen exposure are present because these sites increase direct and indirect contact with interspecific species, conspecific species, and carcasses compared to feeding areas without anthropogenic influences. When feasible, carcasses should be buried daily to avoid attraction to these sites or placed in layers with other organic material to compost quickly and reduce availability to scavengers.

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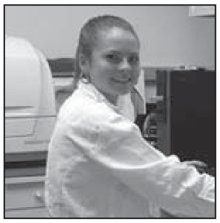

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