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PROSPECTS FOR RESTORING RIVER OTTERS IN INDIANA

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ABSTRACT. Native populations of the North American river otter (*Lontra canadensis*) in Indiana declined sharply through the early 1900s due to unregulated harvest and habitat loss and were believed extirpated from the state by 1942. To restore otters to portions of their historic range, 303 otters (184♂:119♀) obtained from Louisiana were released at 12 sites in six watersheds (Muscatatuck, Patoka, south-central Ohio, St. Joseph, Tippecanoe, upper Wabash) between 1995 and 1999. Fifty-nine (43♂:16♀) of these otters (19.5%) were known to have died through December 2005, most (81%) in traps set for other furbearers and from collisions with vehicles. Otter sign was found on 31 of 43 surveys (72%) at each of 11 release sites sampled 0–6 years ($\bar{x}$ = 2.5) post-release. Overall detection rate was 20.6%. A total of 1328 post-release records, comprised of sightings (n = 884), accidental captures (n = 17), reports of otter sign (n = 170), and mortalities (n = 257) was compiled from 1995 through 2005. During this period, river otters were reported from 65 of 92 counties and 14 of 15 watersheds in Indiana. They are widely distributed in northeast, northcentral, and southern Indiana but are most common in 26 contiguous counties surrounding the 12 release sites. Otters are rare or were not reported from 57 counties in central Indiana. Reproduction was confirmed, either by recovery of untagged individuals and/or observations of family groups, each year after the initial release year and at 11 of 12 release sites. Size of family groups averaged 4.2 otters (range = 3–8). Ovulation rates based on presence of corpora lutea were 88% and 50% for adults and yearlings, respectively; mean litter size was 3.25 (SD = 1.12). Source of mortality for 206 (111♂:95♀) untagged otters killed in Indiana was incidental trapping (n = 131), collisions with vehicles (n = 68), drowning (n = 5), and unknown factors (n = 2); distribution by age class was 54 juveniles (27.3%), 64 yearlings (32.3%), and 80 adults (40.4%). Recommendations for otter management in Indiana include defining occupied range, collecting age-specific reproductive parameters, and developing management strategies to protect, maintain, and regulate restored populations.

Keywords: Distribution, furbearer, Indiana, *Lontra canadensis,* population, reintroduction, river otter, survey

The historical distribution of the North American river otter (*Lontra canadensis*) was widespread and encompassed most major watersheds in the continental United States and Canada (Hall 1981). Indigenous populations, however, declined sharply through the early 1900s, primarily due to unregulated trapping, water pollution, and habitat losses associated with human encroachment (Melquist & Dronkert 1987; Polechla 1990; Melquist et al. 2003). Such declines were especially severe in the central plains and midwestern regions of the United States (Hamilton & Fox 1987) where aquatic habitats were sparse and extensive agricultural activity had eliminated or degraded many wetland communities and riparian systems. In Indiana, native populations were also greatly reduced by the turn of the century (Lyon 1936). River otters were first protected in Indiana in 1921. Prospects for recovery, however, were unlikely; and they were believed to have been extirpated from the state by 1942 (Mumford 1969). Rangewide, otters were reported absent from five states, including Indiana, and protected in 17 others in 1976 (Deems & Pursley 1978).

During the 1970s, advances in furbearer management and broad environmental initiatives to improve water quality and protect or restore wetland and riparian habitats improved conditions for river otters in North America (Endangered Species Scientific Authority

1978). As a result, several state agencies began reintroduction projects to restore or enhance diminished otter populations in portions of their historic range. These initial efforts proved an effective strategy for recovery, and by 1998, over 4000 otters had been released in 21 states (Raesly 2001). Several states reported initial successes shortly after releases (e.g., Serfass & Rymon 1985; Erickson & McCullough 1987; Erickson & Hamilton 1988; Bluett et al. 1999; Johnson & Berkley 1999). Most reintroductions were ultimately considered successful (Raesly 2001); and by 2004, several states (e.g., Missouri, Kentucky, Ohio) had initiated or proposed regulated harvests of restored otter populations.

Although most reintroduction projects began more than 15 years ago, there are few published accounts that assess their long-term status and efficacy in restoring viable otter populations. In Pennsylvania, Serfass et al. (1993) documented a self-sustaining otter population 6–8 years post-release, which subsequently contributed to a statewide range expansion (Serfass et al. 1999). Hamilton et al. (2000) described unanticipated otter-human conflicts and management challenges following a highly successful program in Missouri. Bluett et al. (2004) reported a statewide distribution of otters and recommended de-listing following releases in Illinois. Herein, we provide a comprehensive evaluation of otter restoration efforts in Indiana from its origin in 1995 through 2005. We document population stability and growth, range expansion, and reproductive success during this 11-year period and discuss the species' legal status and impending issues concerning management of river otters in Indiana.

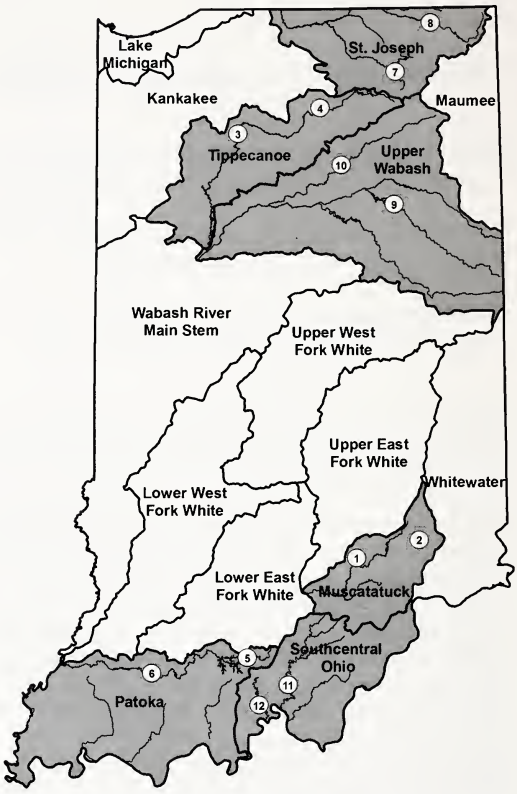

Figure 1.—Watersheds delineated for river otter restoration in Indiana. Shaded watersheds (n = 6) were identified by Johnson & Madej (1994) as highest priority for restoration. Numbered circles (○) represent location of release sites (n = 12) listed in Table 1.

METHODS

Otter releases.—Johnson & Madej (1994) delineated 15 watersheds in Indiana, and based on habitat quality, identified the Muscatatuck, Patoka, southcentral Ohio, St. Joseph, Tippecanoe, and upper Wabash as most suitable for otter restoration. These six watersheds were located in northeast, northcentral, and southern Indiana (Fig. 1).

Wild-trapped otters were purchased from a private supplier in coastal Louisiana (L.R. Sevin, Bayou Otter Farm, Theriot, Louisiana) because they are of the same subspecies native to Indiana (*Lontra canadensis laxitina*) and were used successfully in other midwestern states (e.g., Illinois, Iowa, Ohio, Missouri; Raesly 2001). Otters were captured in Louisiana during open trapping seasons using modified foothold traps and restraint techniques to reduce injury (Shirley et al. 1983). They were held in captivity for up to ten weeks before being transported to Indiana in agency vehicles, typically in late January. Upon arrival, otters were examined at the School of Veterinary Medicine, Purdue University and treated for trap-related dental or foot injuries (e.g., broken canines, lacerations, fractured digits). Each otter was administered ivermectin for internal parasites and multivalent vaccine products (e.g., Eclipse® 4, Fel-O-Vax® PCT, Vanguard® 5 CV-L) containing antigens for canine and feline diseases (i.e., distemper, rhinotracheitis, panleukopenia). A

Table 1.—Summary of river otter releases in Indiana, 1995–1999. Number in brackets denotes location of release site in Figure 1. Big Oaks National Wildlife Refuge was Jefferson Proving Ground at time of releases.

Watershed/release site	County	Release period(s)	No. otters released	Sex (M:F)
Muscatatuck River watershed				
[1]—Muscatatuck National Wildlife Refuge	Jackson	Jan 1995	25	15:10
[2]—Big Oaks National Wildlife Refuge	Ripley	Jan 1996; Jan 1999	31	19:12
Tippecanoe River watershed				
[3]—Tippecanoe River State Park	Pulaski	Jan, Feb 1996	26	16:10
[4]—Etna Green (Tippecanoe River)	Kosciusko	Jan 1996	24	14:10
Patoka River watershed				
[5]—Patoka Lake	Orange	Jan 1997	24	14:10
[6]—Sugar Ridge Fish & Wildlife Area (Patoka River)	Pike	Jan 1997	25	16:9
St. Joseph River watershed				
[7]—Mallard Roost WCA (South Branch Elkhart River)	Noble	Jan, Feb 1997; Jan 1998	27	17:10
[8]—Pigeon River Fish & Wildlife Area (Pigeon River)	Lagrange	Jan 1998	25	15:10
Upper Wabash River watershed				
[9]—Salamonie Lake	Huntington	Jan 1998	25	15:10
[10]—Eel River	Wabash	Jan 1998	25	15:10
Southcentral Ohio River watershed				
[11]—Blue River	Crawford	Feb 1999	23	14:9
[12]—Little Blue River	Crawford	Feb 1999	23	14:9

numbered Monel® fingerling and No. 3 tag was placed in each ear and interdigital membrane of the hind foot, respectively. Unless held for observation or rehabilitation, otters were released 3–4 days after their arrival in Indiana.

We released otters at two sites within each of the six watersheds (Fig. 1). Overall, 303 otters (184♂:119♀) were released during five consecutive winters between January 1995 and February 1999 at 12 sites in 11 counties. An average of 25.3 otters (range = 23–31) was released per site at a mean sex ratio of 1.55 males per female (Table 1). Otters exhibit delayed implantation that can postpone parturition for *ca.* 12 months after copulation (Liers 1951; Hamilton & Eadie 1964). Therefore, otters were released in late January, before peak breeding season, to improve the prospect that females would mate and bear young in their second spring after release.

Post-release field surveys.—Field surveys for otter sign (i.e., tracks, slides, scats, latrines, prey remains) were conducted during six winters between February 1996 and January 2001. Survey routes were limited to release sites and surrounding drainages within the six targeted watersheds. On each survey, accessible points along waterways (e.g., bridges, boat ramps) were visited to record the presence of otter activity. No limits were set on the length of stream bank examined, number of points visited, their distribution in the survey area, or proximity to one another. Number of nights elapsed since the last measurable snowfall, percent ice cover, snow depth, and type of otter sign (if present) were recorded at each survey point.

Post-release records of otters.—A variety of approaches was used to increase public awareness of Indiana's river otter restoration program and encourage post-release reporting of otter activity. Most releases received substantial media coverage by local, regional, and statewide newspapers and television stations and were well attended by the public. To solicit reports, "River Otter Release Area" signs were posted at release sites, boat ramps, and bait shops, and notices encouraging the reporting of otter sightings were published in annual hunting and trapping regulation booklets. Periodic news releases and articles in

Table 2.—Sources of mortality for river otters released in Indiana, 1995–1999. Distance expressed as linear distance to release site.

			Both sexes					
	n		Distance (km)			Days since release		
Source	Males	Females	Mean	SD	Range	Mean	SD	Range
Trapping	20	9	50.0	61.5	1.7–239.0	888	548	41–2149
Road-kills	13	5	29.3	36.5	3.1–152.3	478	761	4–2234
Unknown	3	2	18.2	27.1	2.1–65.6	130	146	44–298
Drowning	2	0	191.0	253.6	11.7–370.4	972	774	425–1519
Stress/exposure	2	0	8.2	2.6	6.3–10.0	6	1	5–6
Research-related	1	0	3.1	—	—	5	—	—
Shooting	1	0	2.5	—	—	2	—	—
All sources	42	16	42.0	67.6	1.7–370.4	630	661	2–2234

popular magazines generated other reports. Date, location, number of otters, and type of observation (e.g., sighting, road-kill, tracks, slides) were recorded for each report. Observers lacking experience with otters were contacted directly to evaluate the validity of their account. Licensed trappers, anglers, and personnel from federal and state natural resource agencies also provided reliable reports of otter activity.

Carcass examinations.—We attempted to recover the carcasses of all otters reported killed in Indiana between 1995 and 2005. Date, location, cause of death, sex, and physical condition were noted for each mortality. A lower canine was extracted and sent to a private facility (Matson's Laboratory, LLC; Milltown, Montana) for age determination using cementum annuli analysis. A parturition date of 1 April was used to assign otters into three age classes: juveniles (< 12 months of age), yearlings (1–2 years), and adults (> 2 years). We examined each carcass for ear and/or web tags and also searched for intraperitoneal transmitters used to monitor 15 otters in our first release (Johnson & Berkley 1999). Reproductive characteristics of females were assessed by examining ovaries and uterine horns for presence and number of corpora lutea, blastocysts, and embryos using methods described by Hamilton & Eadie (1964) and Gilbert (1987).

RESULTS

Fate of founder otters.—Fifty-nine (43♂:16♀) of the 303 otters (19.5%) released in Indiana were known to have died between January 1995 and December 2005. Otters killed in traps legally set for other furbearers (n = 29), primarily beaver (*Castor canadensis*), and collisions with vehicles (n = 19) accounted for 81.4% of the known mortalities (Table 2). Two males released at Big Oaks National Wildlife Refuge (NWR) were found dead within one week during an extended period of exceptionally severe winter weather. Both were recovered near frozen intermittent drainages within 10 km from the release site and were deplete of fat reserves; cause of death was presumed to be release-related stress and associated exposure. Two males drowned in commercial fishing nets, one was shot, and another died from an abdominal infection eight days after surgery to implant an intraperitoneal transmitter. Cause of death for five otters recovered post-mortem was unknown because of inconclusive evidence or advanced autolysis.

Time and point of release for eight otters (3♂:5♀) were unknown because they had lost their identification tags. They were killed 1.7–73.8 km ($\bar{x}$ = 19.4) from the nearest release site and had distinctive split ear pinnea and punctured or torn interdigital membranes where tags had been affixed. The remaining 51 otters traveled an average of 42.0 km (SD = 67.6), but most (53%) were killed within 15 km from their release site. Eight otters (7♂:1♀) were recovered in Kentucky (n = 5), Illinois (n = 2), and Michigan (n = 1), but the greatest distance traveled was 370 km for a male from Salamonie Lake that drowned 14 months post-release in a commercial fishing net in the lower Wabash River. Seventeen (35%) deaths occurred within two months af-

Table 3.—Summary of post-release field surveys for river otter activity near 11 release sites in Indiana, February 1996–January 2001. Overall detection rate is expressed as percent of points on all surveys conducted at a release site at which otter sign was confirmed.

				Surveys with otter sign		All surveys
Release site	No. surveys	Mean years (range) elapsed since release	Mean ± *SD* points per survey	*n*	Mean percent (range) of points with otter sign	Overall detection rate
Muscatatuck NWR	7	5.0 (4–6)	11.7 ± 10.5	4	25.0 (12.5–45.7)	25.6
Big Oaks NWR	9	2.8 (0–5)	15.1 ± 7.8	5	18.4 (7.7–37.5)	10.3
Tippecanoe River SP	2	0	16.5 ± 2.1	2	32.2 (11.1–53.3)	30.3
Etna Green	3	1.7 (0–5)	22.7 ± 19.3	3	29.8 (27.3–33.3)	29.4
Patoka Lake	2	2.0 (1–3)	27.0 ± 4.2	2	20.8 (16.7–25.0)	20.4
Sugar Ridge FWA	9	2.4 (1–4)	11.2 ± 3.6	5	27.7 (6.3–57.1)	17.8
Mallard Roost WCA	4	0.8 (0–2)	10.3 ± 1.3	3	36.7 (16.7–60.0)	26.8
Salamonie Lake	2	2.5 (2–3)	17.5 ± 0.7	2	20.3 (11.1–29.4)	20.0
Eel River	1	2.0	46.0	1	15.2	15.2
Blue River	2	1.5 (1–2)	15.0 ± 7.1	2	25.0 (20.0–30.0)	23.3
Little Blue River	2	1.5 (1–2)	16.5 ± 3.5	2	31.0 (26.3–35.7)	30.3
All sites	43	2.5 (0–6)	15.3 ± 9.5	31	25.9 (6.3–60.0)	20.6

ter release, and over half (51%) occurred within one year. Two males were struck by vehicles more than six years post-release 13.2 and 19.7 km from their respective release site, and a female released at Pigeon River Fish & Wildlife Area (FWA) was killed in a beaver trap 7.8 km away nearly six years later. Mean number of mortalities from each site was 4.3 ± 2.2, which comprised from 8–36% ($\bar{x}$ = 16.7%) of the number of otters released per site.

Post-release field surveys.—We conducted 43 surveys between February 1996 and January 2001 and located otter sign on 31 (72%) routes in the 11 release sites sampled (Table 3). An average of 25.9% of the points visited on these 31 surveys had otter sign (range = 6.3–60.0%). Pigeon River FWA was the only release site not sampled; mean number of surveys at the remaining 11 sites was 3.9 (range = 1–9). Surveys were run an average of 2.5 years (*SD* = 1.9) after otters had been released, but most (81%) were conducted within four years. Eight surveys (19%) at Big Oaks NWR, Tippecanoe River State Park (SP), Etna Green, and Mallard Roost Wetland Conservation Area (WCA) were conducted only 11–23 days ($\bar{x}$ = 17.1) after otters had been released. Sign was detected on seven (88%) of these surveys at 0–60% ($\bar{x}$ = 28.3%) of the points. Otter sign, however, was also found at 0–45.7% ($\bar{x}$ = 16.9%) of the points on five of eight surveys (63%) at three sites (Etna Green, Big Oaks NWR, Muscatatuck NWR) that were sampled at least five years post-release. Overall detection rate at all sites averaged 20.6% and ranged from 10.3% at Big Oaks NWR to 30.3% at Tippecanoe River SP and the Little Blue River (Table 3).

Reports of otters and their sign.—We received 1107 sightings from 62 of Indiana's 92 counties; 223 reports were omitted because they were suspect or lacked sufficient information to assess their validity. The remaining 884 sightings occurred in 14 of 15 watersheds, but 849 (96%) originated from the six targeted watersheds. Otter sightings were confirmed in 48 counties, but 17 counties surrounding the 12 release sites accounted for 799 (90%) observations. Number of otters sighted ranged from 1–9 ($\bar{x}$ = 2.0), but sightings of single otters (*n* = 499, 56%) were most common.

Since December 1996, we documented 17 incidents from 13 counties in which otters were accidentally caught but released from snares or foothold traps set for other furbearers. Fifteen (88%) occurred an average of 9.7 km (range = 3.1–22.5) from a release site. The other two otters were trapped in the Kankakee and Whitewater watersheds, 32 and 47 km from the nearest release site, respectively.

Excluding post-release field surveys, 170 reports of otter sign were collected, mostly from licensed trappers or natural resources

Table 4.—Reproductive characteristics of yearling (1–2 y) and adult (>2 y) female river otters (n = 60) collected in Indiana, February 1998 to March 2006. Corpora lutea counts are minimum number that was detected in ovaries. Corpora lutea were present but not counted in one adult.

	No. examined	Corpora lutea			Blastocysts			Implanted embryos		
Age class		n	Mean ± SD	Range	n	Mean ± SD	Range	n	Mean ± SD	Range
Yearling	26	13	2.62 ± 1.04	1–5	6	1.83 ± 0.75	1–3	2	4.00 ± 1.41	3–5
Adult	34	29	2.86 ± 0.99	1–4	8	2.50 ± 1.07	1–4	14	2.93 ± 1.07	1–4
Combined	60	42	2.79 ± 1.00	1–5	14	2.21 ± 0.98	1–4	16	3.06 ± 1.12	1–5

personnel, from 27 counties. Twelve counties, most of which surrounded the six release sites in northern Indiana, accounted for 138 (81%) reports.

Recovery of untagged otters.—A total of 206 (111♂:95♀) untagged otters (i.e., non-founder individuals) was reported killed in 47 Indiana counties through December 2005. Cause of death was incidental trapping (n = 131), collisions with vehicles (n = 68), drowning (n = 5), and unknown factors (n = 2). Age data were available for 198 otters (105♂:93♀); distribution by age class was 54 juveniles (27.3%; 20♂:34♀), 64 yearlings (32.3%; 38♂:26♀), and 80 adults (40.4%; 47♂:33♀). The age of five additional males could not be distinguished between yearling and two-year-old due to indistinct or irregular cementum patterns.

Most untagged otters (n = 177; 86%) were killed in the Muscatatuck, Patoka, St. Joseph, Tippecanoe, and upper Wabash watersheds. Similarly, 14 counties near release sites (Cass, Dubois, Fulton, Gibson, Huntington, Jackson, Jennings, Noble, Orange, Pike, Pulaski, Scott, Wabash, White) each had more than five mortalities that comprised 67% (n = 138) of the total kill statewide.

Evidence of reproduction.—Fifty-two of 884 sightings (5.9%) were of otter family groups reported from 16 counties in eight watersheds. Thirty-seven reports (71%) originated from eight release sites including 20 at Muscatatuck NWR. Family groups were sighted each year except for the first release year (1995). Group size averaged 4.2 otters (range = 3–8) and was typically comprised of one or two adults and 2–5 juveniles ($\bar{x}$ = 2.9).

Untagged juvenile and yearling otters, definitive proof of successful reproduction, were recovered in 36 counties and 12 of 15 watersheds statewide. Most (69%), however, were taken in three of the six targeted watersheds (Patoka, Tippecanoe, upper Wabash). Five counties (Dubois, Fulton, Huntington, Pike, Wabash) surrounding six release sites each had over nine recoveries that accounted for 39% of the total. Untagged otters less than two years of age were also killed in eight counties in six non-targeted watersheds: Kankakee (Laporte, Starke), lower West Fork of the White (Knox), Maumee (Allen), upper East Fork of the White (Decatur), Wabash—main stem (Parke), and Whitewater (Ohio, Switzerland). Lastly, we were encouraged by the high proportion of young otters recovered each year in Indiana. An average of 58% of the untagged, known-age otters killed each year were < 2 years old. Juveniles were recovered as early as March 1996 and comprised 0–100% ($\bar{x}$ = 33%) of the annual total; yearlings consisted of 0–73% ($\bar{x}$ = 25%).

We examined fresh, whole reproductive tracts from 64 non-juvenile females for presence and number of corpora lutea, blastocysts, and embryos. Placental scars were evident in four post-partum tracts collected between 15 March and 8 May. Of the remaining 60 tracts, corpora lutea were present in 13 of 26 (50.0%) yearlings and 30 of 34 (88.2%) adults (Table 4). The degraded condition of ten tracts precluded complete counts of the number of corpora lutea; thus, minimum number of corpora lutea per female averaged 2.62 (SD = 1.04) and 2.86 (SD = 0.99) for yearlings and adults, respectively. Blastocysts were recovered from six of 11 (54.5%) yearling and eight of 15 (53.3%) adult females that had ovulated and did not contain implanted embryos. Mean number of blastocysts per female, however, was only 2.21 (SD = 0.98). Litter size based on counts of implanted embryos (n = 16) and post-partum placental scars (n = 4) averaged 3.25 (SD = 1.12). Most females (63%) with

implanted embryos were taken from mid-December through mid-January and had uterine swellings to indicate embryonic development. Mean crown-rump length (CRL) of 12 embryos from three females killed between 31 December and 24 January was 1.94 ± 0.83 cm (range = 1.10–3.21). Two adults killed on 13 January and 3 March each contained four embryos averaging 7.83 ± 0.30 cm (range = 7.45–8.27) in CRL. Four male fetuses near full term were recovered from an adult killed on 2 March; they averaged 12.27 cm in CRL and weighed 120–130 g ($\bar{x}$ = 125.5). Another adult killed on 7 March contained three fetuses (1♂:2♀) averaging 23.1 cm in total length and weighing 160–166 g ($\bar{x}$ = 162.7).

Cumulative distribution and range expansion.—We used field surveys, sightings, and information from mortalities to assess the distribution and post-release range expansion of river otters in Indiana. Using all data sources (n = 1328 post-release records), otters were reported from 65 of 92 counties during the 11-year period between January 1995 and December 2005 (Fig. 2). We also received, but later omitted, 15 unconfirmed reports from nine additional counties (Clinton, Dearborn, Floyd, Hamilton, Hancock, Monroe, Putnam, Rush, Wayne). Otters occurred in 14 of 15 watersheds, but 94% of the records originated from the Muscatatuck, Patoka, southcentral Ohio, St. Joseph, Tippecanoe, and upper Wabash River watersheds. The only watershed from which otters were not reported was Lake Michigan in extreme northwest Indiana.

River otters are widely distributed throughout northeast, northcentral, and southern Indiana but are most prevalent in 15 counties surrounding the 12 release sites (Fig. 2). These top counties each had more than 20 records ($\bar{x}$ = 71.9; range = 21–320) that accounted for 81% of all records and probably support the highest densities of otters in the state. Eleven adjacent counties (Cass, Crawford, Dubois, Gibson, Harrison, Jefferson, Miami, Posey, Scott, Starke, White) had 10–19 records ($\bar{x}$ = 13.3); they too have relatively high otter numbers, most likely due to dispersal from nearby core populations. Otters are present, but less common, in nine counties that had 4–9 records ($\bar{x}$ = 6.0). Excluding Marion and Newton counties, most lie on the periphery of the six priority watersheds. We consider otters rare in 30 counties in which

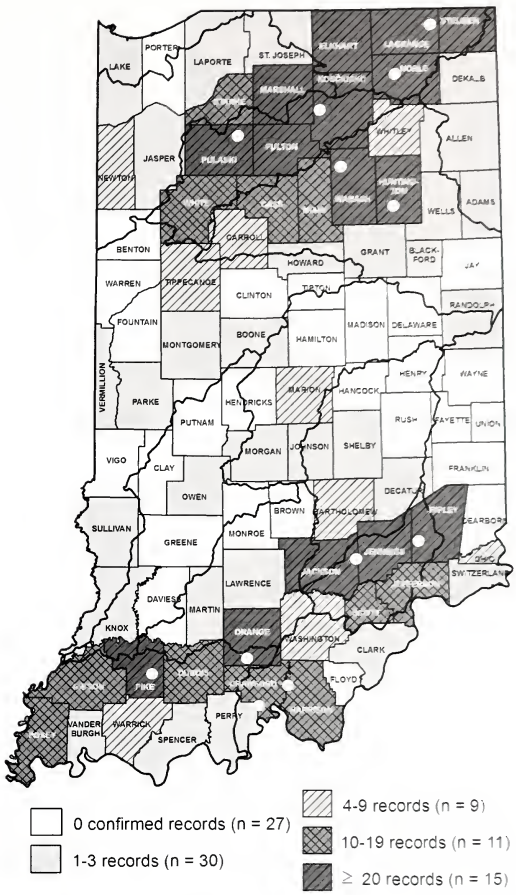

Figure 2.—Cumulative distribution by county of post-release records of river otters in Indiana (n = 1,328) from 1995 through 2005. White circles (○) represent release sites (n = 12). Thick black lines delineate watersheds (n = 15).

there were from 1–3 records. Most of these counties, as well as those from which otters were not reported (n = 27), are in central Indiana (Fig. 2) where land use is typified by human development, urbanization, and widespread agricultural activity. Johnson & Madej (1994) considered watersheds in central Indiana less suitable for restoration, and the few scattered records in this region probably represent transient otters rather than re-established populations. Nonetheless, several larger waterways (e.g., east and west forks of the White River) and their major tributaries had at least 12 records, which suggests some pioneering individuals had colonized these lower priority systems.

DISCUSSION

Otter mortality.—As expected, human-induced factors were significant sources of mortality for river otters in Indiana. Incidental trapping and collisions with vehicles accounted for 61.1% (n = 157) and 32.3% (n = 83), respectively, of 257 mortalities reported in this study. These were also key factors in other state restoration programs (Erickson & Hamilton 1988; McDonald 1989; Bluett et al. 1999; Serfass et al. 1999).

Beavers often enhance conditions for otters because their impoundments create wetland habitats, foraging opportunities, and den sites (Tumlison et al. 1982; Melquist & Hornocker 1983; Dubuc et al. 1990). Otters are particularly vulnerable to beaver trapping (Lehman 1979), yet no special regulations or restrictions were enacted to protect them from accidental take in traps legally set for other furbearers. To minimize losses, however, trappers were encouraged to voluntarily employ methods less likely to take otters, and where possible, otters were released on public properties that already restrict trapping (e.g., Big Oaks NWR, Muscatatuck NWR, Tippecanoe River SP). Nonetheless, sets for beaver accounted for 78% (n = 123) of all trap-related mortalities. Otters were most often killed in body-gripping traps (n = 91) and foothold traps in submergent sets (n = 28) for beaver. Thirty otters (19%) were taken in traps targeting raccoon (*Procyon lotor*). Although incidental trapping was the leading source of mortality in nine of 11 years, losses in the first five years were few ($\bar{x}$ = 4.4/year; range = 0–8) and did not hinder the eventual re-establishment of otters.

Drowning by entanglement in commercial fishing nets is another important source of otter mortality (Mowbray et al. 1979; Anderson & Woolf 1984; Erickson & Hamilton 1988; Bluett et al. 1999). Only four otters (less than 2% of all mortalities) drowned in nets set in Indiana waters, probably because these devices are restricted to the Ohio River and lower to middle reaches of the Wabash, Patoka, and East and West Forks of the White River. Sugar Ridge FWA was our only release site in waterways open to commercial fishing, and two males drowned in a 1.3-km reach of the Patoka River *ca.* 7 km upstream of this site. The other two mortalities occurred in the middle (Vermillion County) and lower (Posey County) reaches of the Wabash River bordering Illinois.

We observed a significant increase (t = 5.82, $P < 0.01$) in the number of mortalities after releases concluded in 1999 (Fig. 3). Between 1995 and 1999, an average of 9.8 (SD = 3.3) otters was reported killed annually; this figure increased to 36.0 (SD = 9.5) in the following six years. Concurrently, the percentage of tagged otters recovered each year declined steadily from a high of 83% (5 of 6 mortalities) in 1995 to only 2% (1 of 41) by 2005. Both trends were considered further proof that otter populations in Indiana were growing and reproducing as anticipated.

Reproductive success.—Excluding 1995, reproduction was confirmed each year, either by recovery of untagged otters and/or observations of family groups. Successful reproduction was ultimately documented at 11 of 12 release sites, often in successive seasons, and other streams statewide. The Little Blue River in the southcentral Ohio River watershed was the only release site at which recruitment was not confirmed. It is a smaller (66 km total length), undisturbed stream in a relatively isolated, sparsely populated region of southern Indiana. Human use is sporadic and mostly limited to occasional recreational pursuits (e.g., canoeing, sport fishing). We compiled only ten records in the Little Blue River since the 1999 release, eight of which were from field surveys. Otter sign, however, was still evident, including at the release site, in 2001 and 2004. Few sightings and lack of reproductive evidence were likely a result of little human presence rather than failure of otters to repopulate the Little Blue River.

Based on presence of corpora lutea, ovulation rates of 88% and 50% were obtained for adult and yearling otters, respectively. Comparable rates were reported for adults from Oregon (98%; Tabor & Wight 1977), Maryland (65%; Mowbray et al. 1979), Maine (77%; Docktor et al. 1987) and Missouri (84%; Hamilton 1998). The reproductive potential of yearling females, however, is less certain. Early studies (Liers 1951; Hamilton & Eadie 1964; Tabor & Wight 1977) concluded female otters do not breed until two years of age. Liers (1958) later reported conception by a 15-month-old female, and others have since reported pregnancy rates in yearlings of

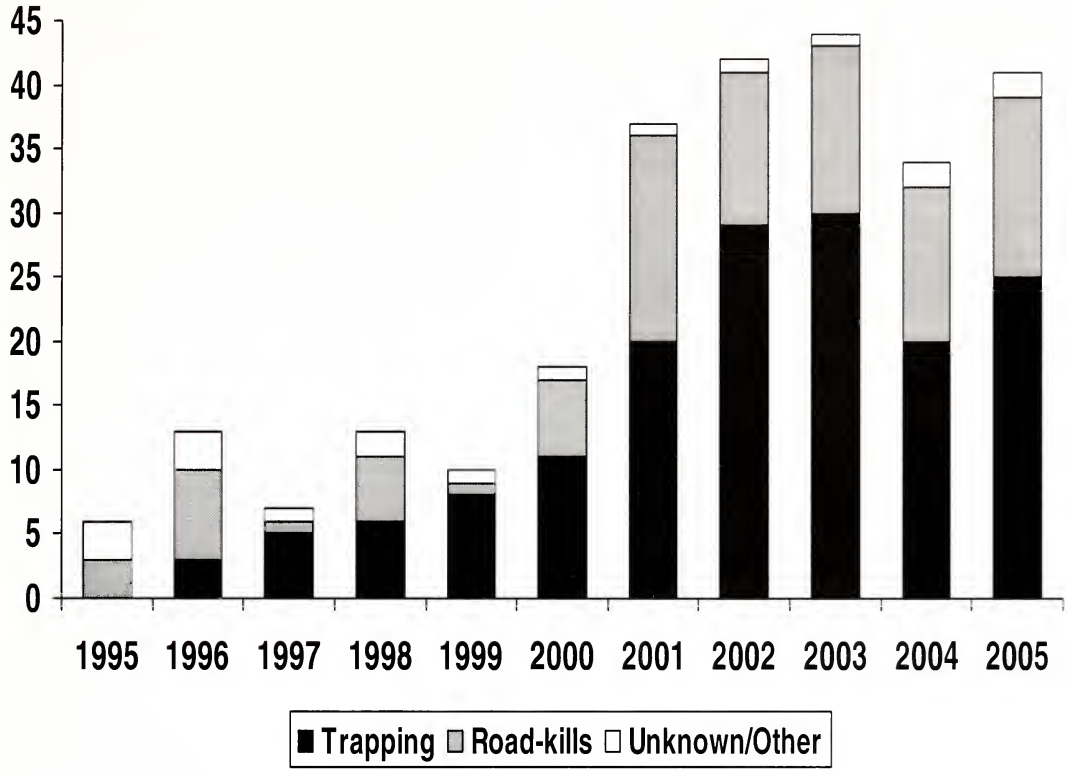

Figure 3.—Number and source of river otter mortalities annually in Indiana, 1995–2005.

7.1% (Mowbray et al. 1979), 33% (Docktor et al. 1987), and 43% (Hamilton 1998). Because otters exhibit delayed implantation, these females would have mated when they were *ca.* 12 months old and subsequently produced their first litter in the spring near the end of their second year. No corpora lutea were found in the ovaries of 27 juvenile females, but two killed between 2–13 March (i.e., *ca.* 11+ months old) each contained three Graafian follicles indicating they had recently ovulated.

Regardless of age class, fewer blastocysts were often recovered from uteri than corpora lutea counted in matching ovaries. This difference is almost certainly due to blastocysts being lost during flushing or destroyed by autolysis, desiccation, and/or poor preservation. Thus, productivity estimates based on blastocysts were biased low when compared to those obtained from corpora lutea and embryo counts (Table 4) as also reported by Chilelli et al. (1996). Although rates of intrauterine mortality appear low in otters (Tabor & Wight 1977; Mowbray et al. 1979), embryo counts still provide the most reliable estimate of litter size (Chilelli et al. 1996). Our estimates, based on either embryo counts ($\bar{x}$ = 3.06; *SD* = 1.12; *n* = 16) or post-partum placental scars ($\bar{x}$ = 4.00; *SD* = 0.82; *n* = 4), compare favorably with those obtained elsewhere. For example, litter size averaged 2.68 in Alabama and Georgia (Hill & Lauhachinda 1981), 2.73 in Maryland (Mowbray et al. 1979), 2.75 in Oregon (Tabor & Wight 1977), and 3.44 for newly restored and increasing populations in Missouri (Hamilton 1998).

Swellings signifying implantation had occurred were noted in the uteri of nine females killed from 28 November to 1 February. The early date may be an anomaly because the tract was from an adult female transported from Louisiana 22 months earlier. Mean date for the eight remaining tracts was 3 January, which suggests parturition in Indiana otters, assuming a 61–63 day gestation period (Larivière & Walton 1998), is well underway by early March and likely extends into April. The reproductive histories of several females further support this timeline. Three fetuses near

full-term were recovered from an adult killed on 7 March, and placental scars were visible in the uteri of females killed on 15 March (n = 2) and 21 April (n = 1). Their reproductive tracts were distended and their teats showed signs of lactation, suggesting they had recently given birth.

Monitoring restored otter populations.—River otters are inherently difficult to monitor because of their low population densities, high mobility, secretive nature, and use of poorly accessible habitats (Erickson & Hamilton 1988; Ralls 1990). These factors are likely exacerbated in the initial stages of restoration when numbers are inevitably low before populations become re-established. Our post-release field surveys were intended only to document presence and distribution near release sites; and otter activity was detected in each watershed sampled, including three sites that were visited five and six years post-release. Although most sign was near release sites, we also found evidence otters used adjacent habitats and other waterways in the six priority watersheds. Therefore, other drainages were surveyed in subsequent winters to improve the prospects of detecting emerging populations elsewhere in the state. Since 2002, these surveys still found otter sign in the six priority watersheds as well as the upper East Fork of the White, upper West Fork of the White, lower West Fork of the White, and Whitewater river watersheds.

Public interest and enthusiasm in otter restoration was keen during the release phase, which created a high profile atmosphere conducive to reporting of sightings, particularly near release sites where otters were visible. Bluett et al. (1999), however, cautioned frequency of observations depends on collection effort and changes in public sentiment as otters become established and less of a novelty. As anticipated, there was a steady decline in the number of observations reported annually after our releases concluded in 1999. Only 258 of 884 sightings (29%) were reported since 2000, including 26 in 2004 and 29 in 2005, the fewest during the 11-year study. We attribute this decline to waning public interest as otters became more commonplace and concur with Woolf et al. (1997) that sightings lose their utility as an effective tool to monitor otter populations over time.

Regional perspective.—River otters are highly mobile as demonstrated by eight individuals released in Indiana that were later recovered in adjacent states. Bluett et al. (1999, 2004) attributed immigration of otters from neighboring states of Iowa, Missouri, and Wisconsin contributed to population growth in Illinois. Dispersal of otters from Ohio and Maryland also facilitated range expansion in Pennsylvania (Serfass et al. 1999). Accordingly, we anticipate releases of over 700 otters in Illinois and Kentucky during the 1990s (Raesly 2001) to aid re-establishment in Indiana waterways bordering these states. In fact, otters possibly had already colonized the Kankakee River prior to our first release in northern Indiana in 1996. A male was trapped on LaSalle FWA in 1994, and otter sign was reported on the Kankakee River in Lake and Newton counties in 1996 and 1997. Although we compiled 22 records in the Kankakee watershed, it's possible that early reports, all within 15 km from Illinois, were from transient otters immigrating into Indiana along the Kankakee River. Additionally, releases in southeast Illinois (Bluett et al. 1999) may bolster recovery in western and southwest Indiana while releases in northern Kentucky may contribute to colonization of Ohio River tributaries in southern Indiana.

Legal status and considerations.—River otters were first given complete protection in Indiana in 1921 (Lehman 1982) and were subsequently listed as endangered by the Indiana Department of Natural Resources (IDNR) in 1969. The species' status was changed to extirpated in 1986, however, because conclusive evidence of a remnant population in the state was lacking. In 1994, the IDNR reclassified the otter as endangered in anticipation of forthcoming restoration efforts.

Endangered species are defined by statute (IC 14-2-8.5-1) as any species or subspecies of wildlife whose prospects for survival or recruitment within the state are in jeopardy or are likely to become so within the foreseeable future. The goal of Indiana's river otter restoration program was to re-establish otter populations in six priority watersheds. Although quantitative delisting criteria were not developed at the onset of the program, restoration efforts to date have met, and in some cases exceeded, the stated program goal. The six targeted watersheds accounted for 94% of the post-release records documented in this study.

Multiple lines of evidence indicate otters are consistently reproducing in these watersheds, and core populations surrounding release sites are self-sustaining and secure. Further, otters have expanded to adjacent habitats, colonized watersheds not initially targeted for restoration, and were documented in > 70% of Indiana's counties in the 11 years following the program's inception. These data indicate long-term prospects for maintaining healthy populations were favorable, and in 2005, the IDNR removed the river otter from endangered status in the state.

The rapid and widespread return of river otters to portions of Indiana was not unexpected. Strategies that were successful in the initial release at Muscatatuck NWR (Johnson & Berkley 1999) were used throughout the program. By 1995, releases in adjoining states had concluded or were nearing completion, and many programs were already reporting stable or growing otter populations (Raesley 2001). Such successes, however, may also generate unexpected social conflicts such as those experienced in Missouri with local sport-fishing interests, private pond owners, and aquaculture facilities (Hamilton et al. 2000). Few complaints have been received from anglers on the impacts, real or perceived, of otters on native sport fish populations in Indiana waterways. Reports of otter depredation from pond owners, however, are a more common and recent phenomenon (10 of 18 complaints since 2004). These ponds are typically small (*ca.* 1 ha) and often close to release sites where otter densities are likely highest. As restored populations continue to grow and expand, nuisance complaints at private ponds and aquaculture facilities in Indiana are likely to become more widespread and numerous.

Melquist & Dronkert (1987) described a comprehensive management program for river otters that included elements of conservation (e.g., reintroductions, habitat preservation, identification and control of limiting factors, regulation of mortality) and population regulation (e.g., sustained yield harvest, damage control). Thus far, otter management in Indiana has focused on the initial components of conservation, primarily reintroductions and protecting and monitoring restored populations. As otter numbers continue to increase as expected, management strategies should explore opportunities to regulate populations and alleviate legitimate depredation complaints where appropriate. Most midwestern U.S. states that reintroduced otters before Indiana (i.e., Missouri, Kentucky, Iowa, Ohio) have already enacted or proposed regulated harvests of restored populations. An average of 27.2 otters (range = 21–37) was reported accidentally trapped during the last five fur harvest seasons in Indiana, but the extent of unreported, trap-related mortalities is unknown. Key population monitoring activities, however, should continue to better define otter distribution and identify age-specific reproductive parameters. These data will become increasingly important as management strategies progress toward a more holistic approach of protection, maintenance, and regulation of restored otter populations.

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