Effects of Roadkill Mortality on the Western Painted Turtle (*Chrysemys picta bellii*) in the Mission Valley, Western Montana

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Abstract

I monitored a population of western painted turtles (*Chrysemys picta bellii*) in the pothole region of the Mission Valley (western Montana) in response to local concern about intense roadkill mortality on U.S. Highway 93 and a proposal to widen the highway. Road-killed turtles were collected from May through August 1995 along a 7.2 km section of US 93 adjacent to the Ninepipe National Wildlife Refuge. Femurs were removed from each dead on the road (DOR) turtle for laboratory age determination (sectioning at Matson's Lab, Milltown, MT). Turtle mortalities spanned the monitored section of U.S. 93 and occurred throughout the field season. A total of 205 turtles were found DOR. Additional turtles were probably killed but did not remain on the road for collection; others were killed outside of the field season. The DOR turtles ranged from 0 to 26 years old ($x = 10.1 \pm 6.27$, $n=125$). Of the DOR turtles, 43% were adult males, 26% were adult females, and 31% (including juveniles) could not be sexed. Seven gravid females were found DOR (13% of the specimens known to be female). We compared age distributions of live turtles in ponds next to the road to the age distributions in ponds further from the road. In addition, we estimated population densities in these ponds and found that population density increases with distance from the highway. Management recommendations are suggested based on roadkill data and literature review.

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Introduction

Roads cause habitat fragmentation for many species by impeding movements, resulting in long and short term impacts. Over the long term, habitat fragmentation causes loss of genetic variability (Oxley et al. 1974, Diamond 1975, Adams and Geis 1983, Reh and Seitz 1990, Bury 1994). This can eventually lead to inbreeding depression, increased risk of local extinctions, and decreased ability to recolonize after such extinctions. Reh and Seitz (1990), for example, showed significant declines in genetic variability in common frog (*Rana temporaria*) populations separated by highways. Immediate effects of barriers and the construction of roads are loss of habitat and roadkill mortality. In this study, I addressed the latter issue for a population of western painted turtles (*Chrysemys picta bellii*) in the Mission Valley of western Montana.

Although roads may be only semi-permeable barriers to species that can cross quickly or fly over, they become less permeable with increased traffic density and speed (van Gelder 1973, Rosen and Lowe 1994, Fahrig et al. 1995) and with increased "clearance," the width of the road or right of way (Oxley et al. 1974, Mader 1984). On the floor of the Mission Valley, U.S. Highway 93, a 2-lane highway, passes through a network of prairie pothole wetlands, and the volume of roadkilled turtles has raised public concern in recent years.

The objectives of this study (in progress) were to define life history traits for this population of painted turtles, develop a model for predicting turtle ages, estimate turtle density in several ponds in the pothole region, and describe the effects of roadkill mortality in terms of its differential impact on the sexes, age classes, and turtle densities in ponds at varying distances from Highway 93. In this paper, I will discuss the last objective. The study is a cooperative effort between the Montana Department of Transportation (MDOT), the Confederated Salish and Kootenai Tribes (CSKT), and the University of Montana's Cooperative Wildlife Research Unit to respond to public concern apparent during scoping meetings in the winter of 1995. The MDOT held these meetings to allow public comment on a Draft Environmental Impact Statement that describes options for widening the highway (USDT FHWA 1995).

Conservation of Long-lived Organisms

Life history characteristics of long lived vertebrate species, such as late maturity and high adult survival rates, reduce their ability to withstand high mortality and chronic disturbances (Congdon et al. 1993). Among ectothermic vertebrates, these include sharks (NOAA 1991), crocodilians (Turner 1977), some fish (Roff 1981), snakes (Brown 1993), and several turtles (Doroff and Keith 1990, Brooks et al. 1991, Congdon et al. 1993, Congdon et al. 1994). Male western painted turtles may live as long as 31 years with age of sexual maturity estimated at 5 years. Females live up to 34 years and reach sexual maturity at age 7 (Wilbur 1975, Frazer et al. 1991).

Life history traits that coevolve with longevity are major factors that leave long-lived species vulnerable to population decline when facing even slight increases in mortality. Maintenance of a stable population of Blanding's turtles (*Emydoidea blandingii*) in Michigan requires a level of juvenile survivorship that is significantly higher than that documented for any other vertebrate (Congdon et al. 1993). Doroff and Keith (1990) showed that a stable population of ornate box turtles (*Terrapene ornata*) in Wisconsin would require an annual adult survival rate of 0.95 or higher, and they found a current annual adult survival rate of 0.81. They concluded that their study population would therefore continue to decline, although the required survival rate may vary from one box turtle population to another. They attributed this decline to human-caused mortality due to roads and automobiles, farm machinery, lawn mowers, and habitat fragmentation by roads and the resulting increased predation along edges (Temple 1987).

Brooks et al. (1991) found that a population of common snapping turtles (*Chelydra serpentina*) may not be able to tolerate a sudden increase in mortality due to otter (*Lutra canadensis*) predation. They predicted population recovery would be slow because the common snapping turtle, as well as other long-lived species, does not exhibit the ability to respond quickly to low population density. Females are not capable of increasing fecundity in response to increased mortality rates. Without increased fecundity or survival of juveniles, this population's recovery may depend on increased immigration from adjacent populations.

Congdon et al. (1994) also found a harvested common snapping turtle population vulnerable to decline. They found that adult and juvenile survival played a more important role in maintaining population stability than did fecundity, age at sexual maturity, or nest survival. Because the common snapping turtle does not respond to decreases in population density, Congdon et al. predicted the number of adults would decrease by 50% in less than 20 years with an increase in harvest mortality of 10% annually on adults over 15 years of age.

Recovery of long-lived, slow-growing species is slow once a population is depressed. Management measures to prevent initial declines therefore may be crucial to the long-term viability of such populations. The painted turtle population in the Mission Valley of western Montana may not be able to tolerate the current or increased levels of roadkill mortality and predation. Our study was designed to help determine management measures necessary to avoid population decline to a point where recovery is difficult or unlikely.

Study Area

The study area is located in the Mission Valley of western Montana, on the Flathead Indian Reservation of the Confederated Salish and Kootenai Tribes (CSKT). The high density wetland area of the Valley floor, consisting of over 2,000 permanent and ephemeral wetlands, is similar to the prairie pothole region of the Dakotas and Canada. The pothole wetlands are close enough for turtles to migrate from one to another, possibly exhibiting a metapopulation dynamic. Highway 93 bisects this network of potholes near the Ninepipe National Wildlife Refuge.

We collected road-killed turtles along a 4.5mi (7.2km) section of Highway 93, the section that runs throughs the concentrated pothole area. The potholes sampled lie on either side of that section of the highway, out to 1.5mi (2.4km) to the east and to the west. In other words, pond sampling took place within a 13.5mi^2 (17.3km^2) area of the pothole region that is bisected by Highway 93.

Methods

Field research methods for this study involved two general processes: roadkill collection and live turtle trapping. The statistical analyses were computed using the SPSS software package.

Roadkill Collection

From May 17 to August 24, 1995, we collected turtles dead on the road (DOR) 3 mornings per week on the section of Highway 93 described above. We recorded the location of each turtle spotted using reflector posts along the roadside to record the location of each roadkill, since they were evenly spaced at 300ft (91.2m) apart. We numbered each one (0 through 60) and estimated DOR turtle locations to the nearest reflector post or nearest midpoint between reflector posts (e.g. to the nearest 150ft, or 45.6m).

After collection, we took several measurements on the turtle shell (if intact), determined its sex, and removed a femur. Turtles were aged from growth annuli counted on cross sections of the femurs. We counted growth annuli and took 5 measurements on each turtle's shell: carapace length, plastron length, plastron width, length of the anterior section of the plastron, and length of the medial annulus on the turtle's right abdominal lamina, the most recent and longest annulus (see Sexton 1959). These were all straight line lengths measured with calipers to the nearest 0.05mm. The number of growth annuli were counted from the laminae on the plastron and recorded as the maximum number found on any one lamina. DOR turtles had often been hit so hard or by so many vehicles that their shells were not intact enough to obtain all, if any, measurements, and sexing was not always possible. The shell measurements and lab-determined ages were used to develop an age-predicting model for live turtles.

At the end of the field season, we walked along the west and east sides of the 4.5mi (7.2km) stretch of highway to record detectable nest site locations in the highway right of way. The only detectable nest sites were depredated nests, where a dug up hole and egg shells are visible, and incomplete nests, which were abandoned nest attempts (empty holes excavated by female turtles). We could not see potentially successful, buried nests.

Live Turtle Trapping

Live trapping occurred from 28 May to 23 August 1995. We sampled ponds along 4 transects perpendicular to Highway 93 in areas where each transect could extend 1.5mi (2.4km) without coming closer than 0.5mi (0.8km) to any secondary roads. We sampled 16 permanent ponds and 7 ponds that dried up over the course of the field season. The analyses only include data from the permanent ponds. We did not sample any ponds with an edge less than 0.25mi (0.4km) from a secondary road, in an effort to reduce variability due to roadkill on these roads.

In each pond, we used basking traps, supplemented in some cases by a baited funnel trap. We checked the trps in each pond every other day. When groups of volunteers were available, we would capture turtles with dip nets or seine nets to increase capture efficiency and sample sizes in some of the ponds.

Each turtle captured was sexed, measured (the same measurements described above), marked, and released. Sexing involved looking for male secondary sex characteristics (elongated foreclaws and preanal region of the tail) on turtles with 4 or more annual growth rings (annuli) on the plastron. The absence of these characteristics indicated a female. Turtles with fewer than 4 annuli were recorded as juveniles because they were generally too young to have secondary sex characteristics and therefore could not be sexed. However, the juvenile definition of less than four annuli only applied during the second half of the field season. Before that, we required the experience of sexing hundreds of turtles to determine an accurate cut-off age for looking for secondary sex characteristics.

We assigned each turtle an individual code and marked it accordingly, using the marking system developed by Dr. Justin Congdon at the Savannah River Ecological Laboratory, South Carolina. Each marginal scute on the carapace was assigned a letter, and the scutes corresponding to the turtle's code were marked with a power drill for turtles larger than roughly 120mm in carapace length. We used a 1/8in bit before 8 August and a 9/64in bit after that date to ensure that codes would last over the long term. Changing the bit size included redrilling all recaptures after 8 August. We used a triangular file, creating a notch at least 1/3 the width of the scute, for smaller turtles. When a marked turtle was recaptured, we recorded its code and repeated the same measurements.

Whenever we spotted a turtle moving overland, we recorded the time of day and the turtle's sex. This was not done systematically, so we did not sample all hours of the day or sample times of day equally. However, these anecdotal observations did give some indication of times of day that turtles are active.

The age-predicting model for the Mission Valley turtle population is based on a regression equation that can be used to estimate the ages of adults or juveniles from plastron width or length, respectively (Fowle, in prep). The age distributions of live turtles are based on that model, and the age distribution of DOR turtles is based on the age determined by Matson's Lab (Milltown, MT) from femur cross sections. Because turtles over approximately 18 years old tend to be as small as most 12 to 14 year-olds, the age distributions show a second pulse around 12 to 14 years, where older turtles are piling up into that category (Figures 4a-4d). Therefore, turtles 12 years and older were examined as one group.

In examining age distributions of live turtles, we only looked at turtles with an estimated age of 4 or older because the trapping method was biased for older turtles. We compared the age distributions of turtles in all ponds <1/4km away from the highway (Distance 1, n=448), to those in all ponds between 1/4 and 1km away from the highway (Distance 2, n=336), and to those in all ponds >1km away (Distance 3, n=233). We also compared the age distribution of DOR turtles to these 3 distributions.

Population densities were calculated on 3 ponds at 3 different distances from the highway using the Lincoln-Peterson model. These three ponds were chosen because of their large sample sizes and high recapture rates and because we were able to do final sweeps with seine nets and dip nets at the end of the field season in these ponds only. Population density analysis is currently in progress, so results presented here are preliminary.

Results

Locations of Roadkills and Nest Sites in the Right-of-Way
We counted 205 DOR turtles and one live turtle on the study section of Highway 93. Their locations spanned the 4.5mi (7.2km) section continuously, with higher concentrations in a few areas (Figure 1). The longest distance between mortality sites for 1995 was about 0.25mi (0.4km). We found 5 detectable nest sites on the east side of the highway and 11 on the west side (Figure 1). (In Figure 1, these sites are mapped farther off to the sides of the highway than they were actually located.)

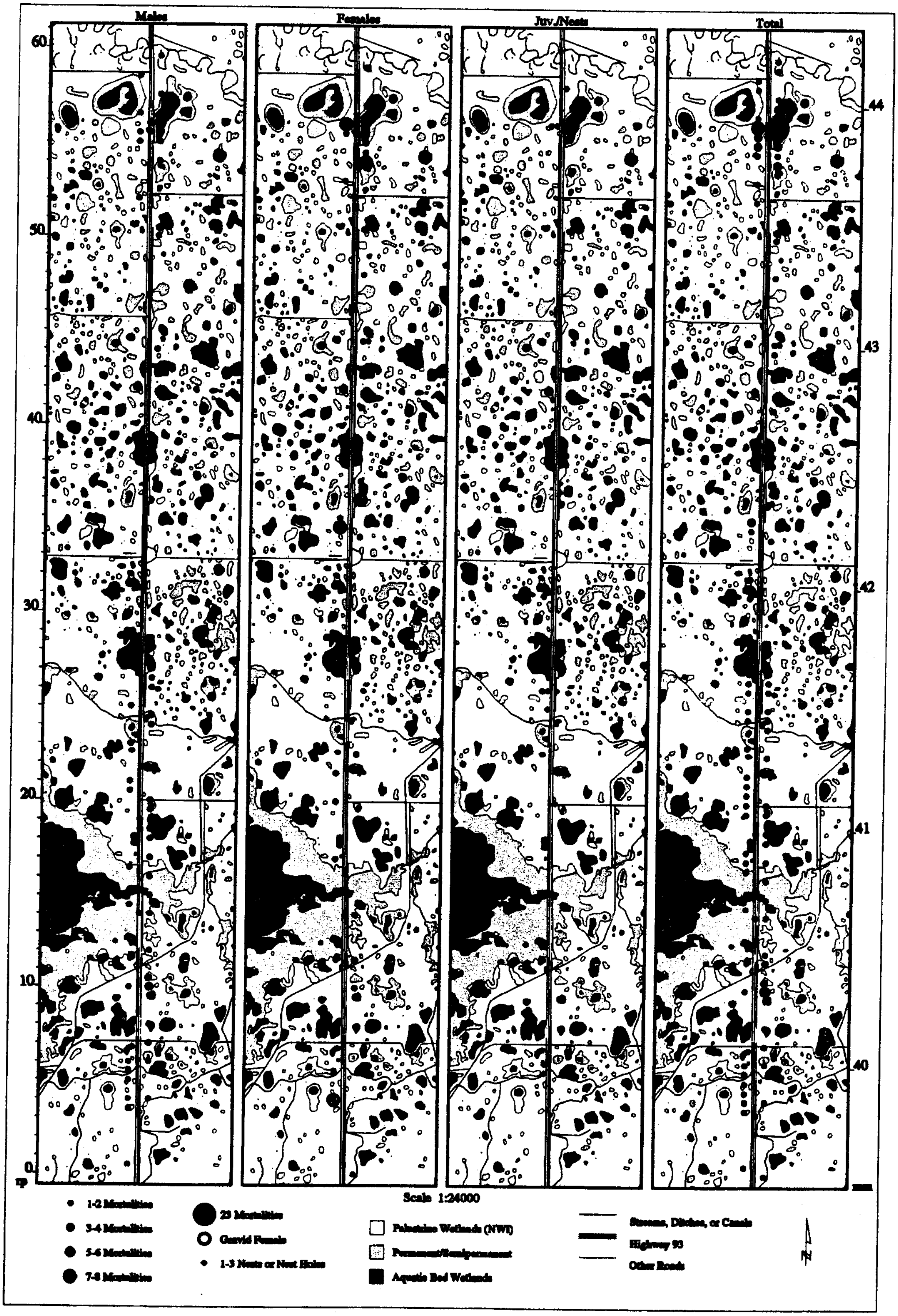
Seasonality of Roadkills
The major pulse of DOR turtles occurred from late May to mid July (Figure 2). Decreases within that pulse occurred briefly in early June and briefly again in mid June. DOR females were collected consistently from mid June to mid July and less consistently outside of that period. This is roughly consistent with the nesting season, late May to early July. Males and juveniles show a more even pattern across the field season.

Sex Ratios
DOR turtles consisted of 26% adult females (n=54), 43% adult males (n=88), and 31% of unknown sex, including juveniles (n=63) (Figure 3a). Seventy-two percent of the juveniles (18 out of 25 total juveniles) were from the area of highly concentrated roadkills (Figure 3b). We were unable to compare the DOR sex ratio (1.6:1) to that of live turtles, because the ponds sampled for live turtles each had different sex ratios (Table 1). Therefore, we do not know if proportionally more males or females were killed on the highway.

Age Distributions
The ponds that were pooled together at Distances 1 and 3 had age distributions that were significantly different from each other, e.g. different *within* the 2 distances (Pearson value=23.62 , P<0.01; and Pearson value=13.4, P=0.01, respectively), while ponds at Distance 2 were not significantly different from each other (Pearson value=4.88, P=0.30). These tests involved ages grouped into 3 stages (4-6, 7-11, and >12 years old), to ensure expected frequencies >5. Because these ponds could not be pooled together for goodness of fit tests between Distances, we examined percentages of turtles belonging to each age class at each Distance (Figures 4a-4d).

The DOR turtle ages were evenly distributed from age 0 to 26, as compared to the distributions of live turtles. Distance 1 contained the highest percentages of juveniles and young adults (ages 4-6), while Distance 2 consisted of the highest percentages of older adults (ages 12 and up). Both Distances 2 and 3 contained more adults and fewer juveniles than ponds at Distance 1. A consistent feature of all the live turtle distributions is a lack of individuals in age classes 7 to 11.

Turtle Movements Detected
According to anecdotal observations, turtles moved during all hours that we were in the field. Adult male movements occurred from 1015 to 1700 (n=10). Juvenile movements occurred from 1415 to 2330 (n=7), and female movements occurred from 0905 to 2130 (n=20). We observed 2 nesting females at 2130 and 2110, but left them undisturbed soon after spotting them. Two females were observed nesting: one from 2130 to 2345 (but did not lay eggs); the other from 2110 to 0135 (from the beginning of digging her nest to when she finished burying her eggs).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Females
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40
30
20
10
0
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43
42
41
40
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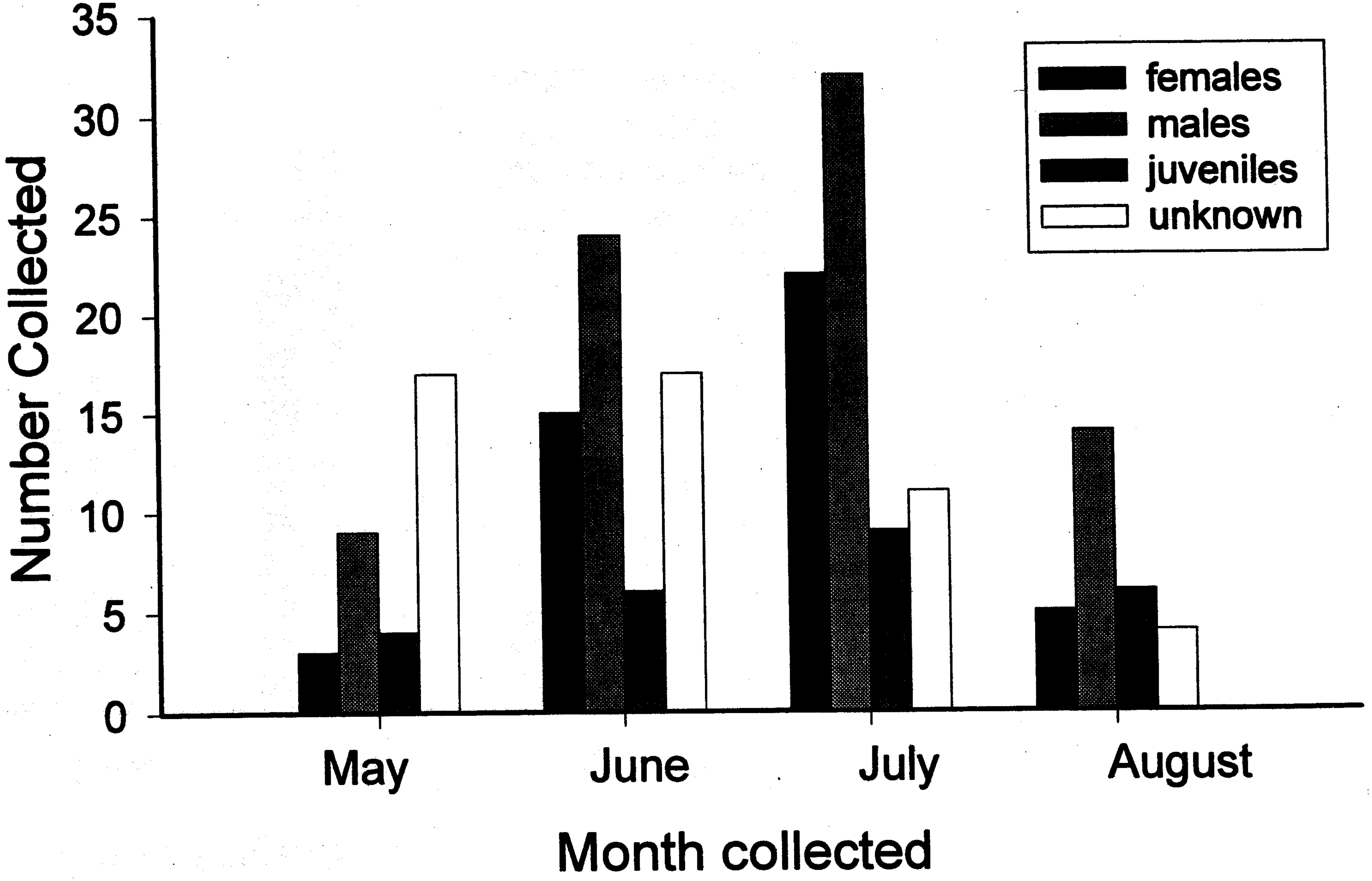
1-2 Mortalities
3-4 Mortalities
5-6 Mortalities
7-8 Mortalities
23 Mortalities
Gravid Female
1-3 Nests or Nest Holes
Palustrine Wetlands (NWI)
Permanent/Semipermanent
Aquatic Bed Wetlands
Streams, Ditches, or Canals
Highway 93
Other Roads
N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25
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15
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June
July
August
Month collected
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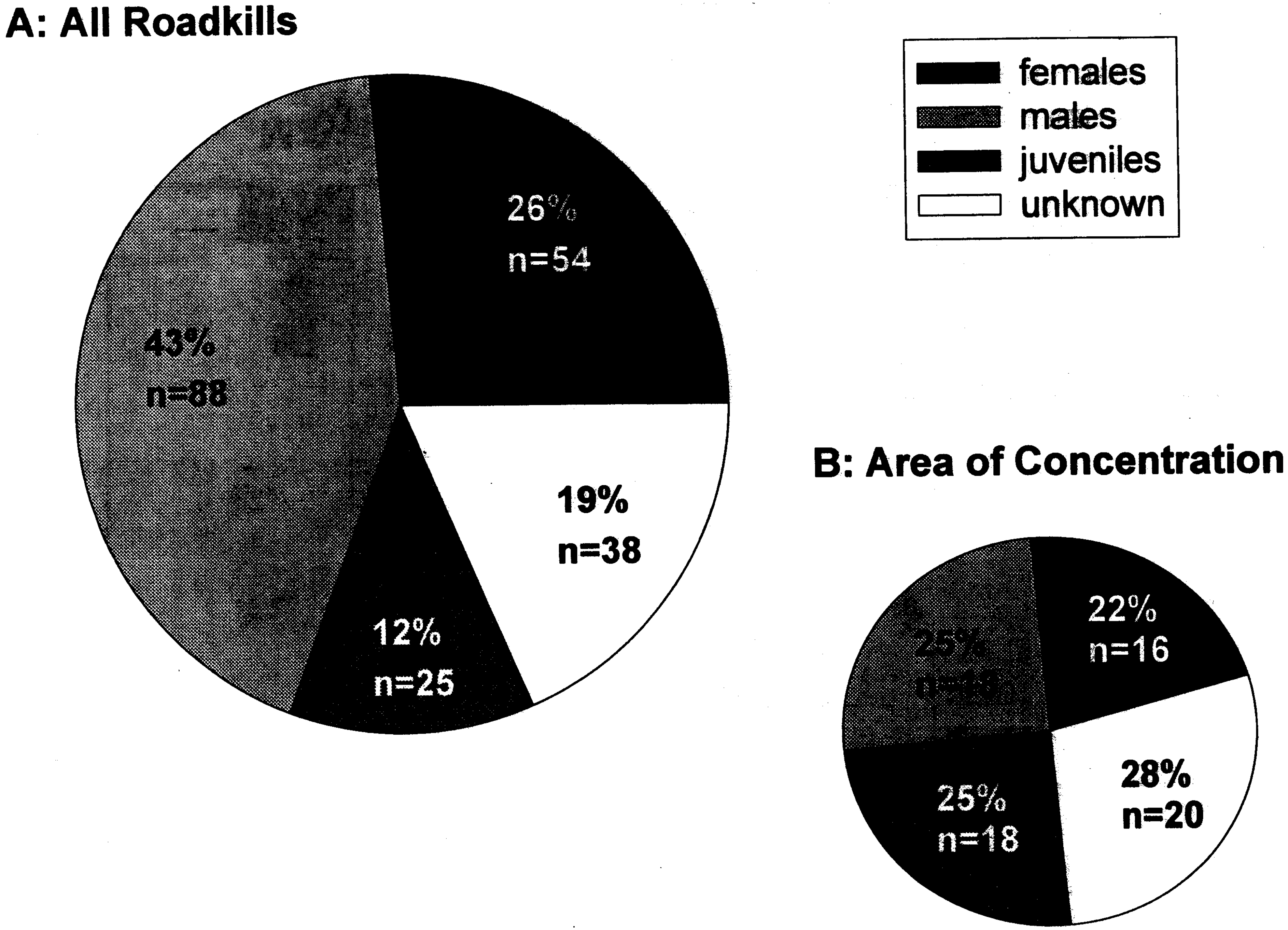
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females
males
juveniles
unknown
26%
n=54
43%
n=88
19%
n=38
12%
n=25
B: Area of Concentration
22%
n=16
25%
28%
n=20
25%
n=18

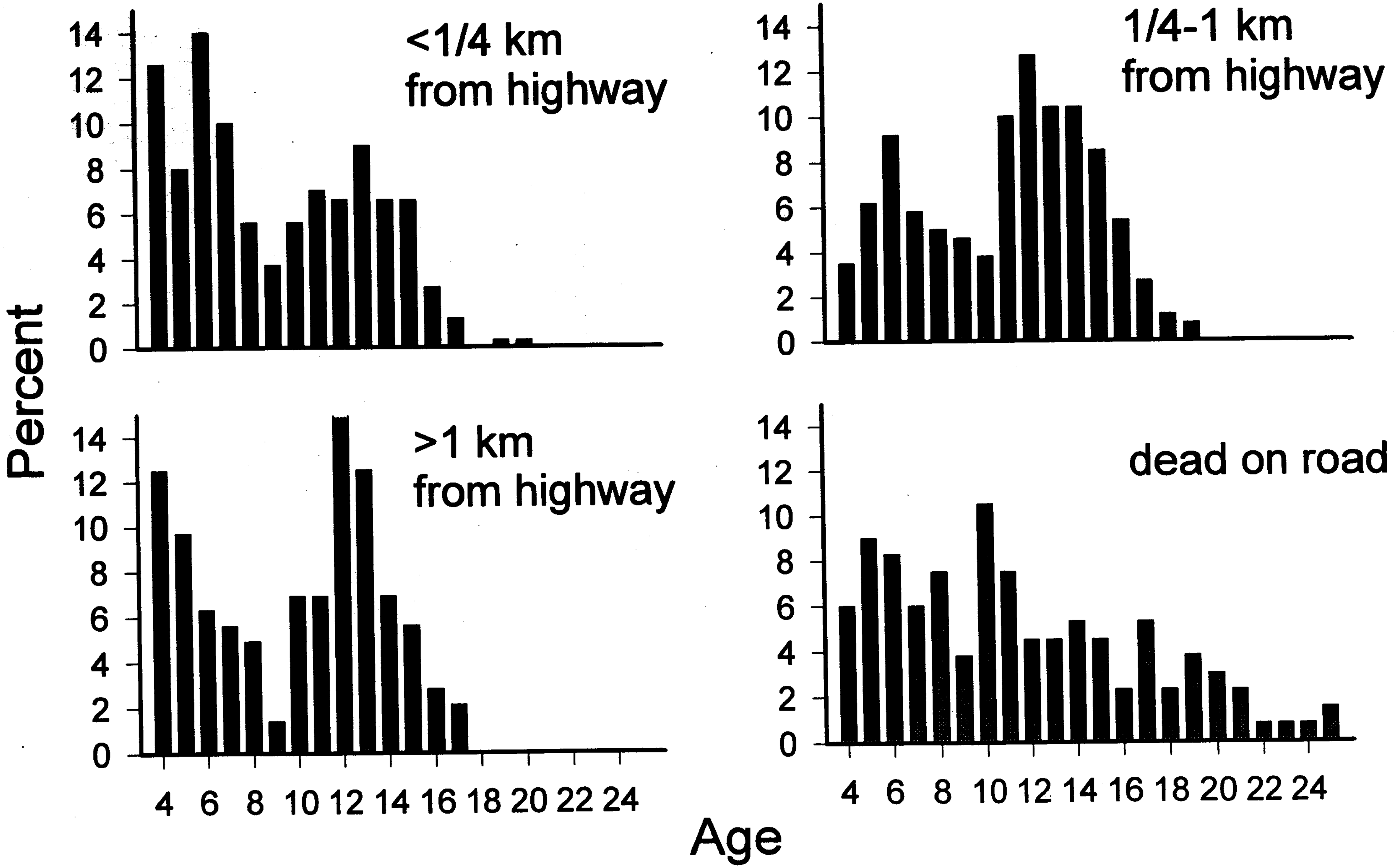
Percent
14
12
10
8
6
4
2
0
<1/4 km
from highway
1/4-1 km
from highway
>1 km
from highway
dead on road
4 6 8 10 12 14 16 18 20 22 24
Age

Table 1. Sex ratios of adult turtles from permanent ponds sampled and found DOR.

Pond no.	DOR	72	168	345	365	613	621	839	877	888	945	1720
sex ratio (m:f)	1.6:1	0.9:1	2.1:1	3.4:1	1.8:1	3.2:1	2.2:1	5.1:1	1.1:1	1.7:1	1.9:1	1.6:1
n	142	113	55	151	89	38	51	67	68	56	38	36

Table 2. Recaptured turtles that moved from the pond of original capture.

Turtle	Sex	PL (mm)	Original capture	Recapture	Distance between ponds (km)
ACH[a]	m	150	June 26	August 18	0.1
NX	m	119	June 22	July 13	0.5
ABCPW	m	107	June 24	August 1	1.1
BL[b]	f	185	June 2	August 22	< 0.1
BNY[a]	j	71	July 22	July 23	0.2
BVX	j	44	July 23	August 1	1.1
IN[a]	j	92	June 20	July 30	3.0

Turtles are listed by their individual codes. PL = plastron length measured on date of original capture; f = female; m = male; j = juvenile. [a]= turtles that moved from temporary pond to permanent. [b]=turtle that moved accross highway.

Table 3. Turtle population density estimates for permanent ponds sampled.

Pond no.	Pond size (ha)	Sample period	Adult population estimate	Juvenile population estimate	Combined population estimate	Density (turtles/ha)	Pond's distance to highway (km)
877	3.4	6/11-8/22	134±56	59±46	193±82	57±24	<0.25
345	2.24	6/14-8/1	255±81	97±19	352±63	157±28	0.6
365	0.54	6/19-7/23	189±108	203±153	392±226	726±419	1.9

Also included in the range of travel times above were 2 females returning from digging nests, detectable by mud on the posterior plastron. These occurred at 0905 and 1130.

From our mark-recapture efforts with live turtles, we found 7 turtles that moved from the pond of original capture to other sampled ponds, where they were recaptured. The distance moved mostly ranged from <0.1 to 1.1km, with one turtle that moved a distance of 3km. We detected 3, 1, and 3 movements among males, females, and juveniles, respectively (Table 2). The female, turtle "BL," moved from one side of the highway to the other. The 7 turtles that moved from the pond of original capture made up 2% of all recaptures (n=354 recaptures). Only 2 of the 205 DOR turtles were known to be marked turtles, and both of these turtles were marked in a pond immediately adjacent to the highway, the same pond in which turtle "BL" was first captured. Many others could have been marked, but the roadkills were usually too damaged to be able to detect the presence of markings.

Population Density Estimates

According to preliminary population estimates, turtle densities did decrease with increased proximity to the highway (Table 3). Because adult and juvenile capture rates were not equal in the basking traps, adults and juvenile population sizes were estimated seperately, then combined to calculate overall density in each pond.

Discussion

Roadkill Locations and Characterization

Without comparable historical data, we do not know whether the total roadkill count (205) is an increase or decrease from previous summers. CSKT biologists have taken roadkill counts in previous years, using different methods and levels of effort. Our data indicate that turtles of all ages and both sexes attempt to cross Highway 93 throughout the summer months. Therefore, mechanisms for increasing the permeability of the road (discussed in the Management Implications section) must accommodate all ages and both sexes and must function at all times when turtles are mobile over land.

The sex ratio, DOR locations, and age distributions we found could be better explained in comparison to historical or future data. For example, the proportion of DOR females we found may be smaller than that of previous years. Many females with historical nest sites across the highway from their breeding ponds may have already been killed. The concentrations of DOR turtles may have shifted as well. Areas where we found low concentrations may be due to higher concentrations in the past and the resulting population decrease.

Potential Effects on the Population

Proportionally more juveniles and proportionally fewer adults were found at Distance 1 than found in both Distances 2 and 3, implying that roadkill mortality may be killing more adults, or killing turtles before they reach adulthood. Roadkill mortality may also be significant enough to cause a decrease in turtle density, thereby decreasing juvenile-adult competition for resources and increasing juvenile survival rates. However, more information on juvenile dispersal and hatchling movements is necessary to understand this age distribution.

Population density estimates support the hypothesis that proximity to the highway results in population decrease (Table 3). Only 1 turtle was caught, using a seine net, in the pond adjacent to the area of highest roadkill mortality. However, this occurred in 3 other ponds that were over 1/4km from the highway. We caught only 1 or 2 turtles in each of these 3 ponds over the course of the field season), so variables other than distance from the highway (e.g. water temperature, pH levels, substrate, dissolved oxygen content) appear to afffect turtle density.

Overland Movements

Gibbons (1990) provided 5 general reasons for extrapopulational (long-range) movement among freshwater turtles. They include: 1) hatchling movements to find water; 2) seasonal movements due to habitat variation; 3) travel to and from overwintering sites; 4) males searching for mates; and 5) females moving overland to nest. At least 3 of the 7 movements we detected can be explained by the second reason because these turtles moved from ponds that dried up over the course of the field season to ponds that remained full of water (see Table 2). McAuliffe (1978) and Sexton (1959) also found that painted turtles migrated out to "satellite" temporary ponds when they filled in the spring and returned to permanent waters when the satellite ponds dried up. Several other studies confirmed freshwater turtles' response to drying of wetlands (Cagle 1944, Sexton 1959, and Gibbons 1990).

McAuliffe (1978) found that 58% of extrapopulational movements were greater than 100m, whereas Gibbons (1968) found 15%. We found a travel distance greater than 100m for 71% of the movements (5 of 7 total movements) (Table 2). This high percentage of travel distances over 100m may reflect the dry conditions during the summer of 1995. Permanent water was farther apart this year than in most years in the Mission Valley.

The 3km distance recorded would require the turtle to have crossed Highway 93. Although adult painted turtles have been known to travel as far as 2.1km (McAuliffe 1978), this turtle was a juvenile and would have had to travel a longer distance. Alternatively, the turtle may have been captured and moved (e.g. for annual "turtle races" in the area), or its code may have been recorded incorrectly. The one female that moved may have moved to nest without returning to her original pond (Gibbons 1990). It is possible that she was helped accross the road by people driving by, as this has been observed on several occasions though less frequently as traffic volume has increased (S. Ball, CSKT biologist, pers. commun.). The fact that we found only one female among all 7 movements agrees with Gibbons' (1990) conclusion that females are more sedentary. However, as discussed earlier, we do not know if the DOR sex ratio also indicates this.

Gibbons (1990) found that freshwater turtles in South Carolina were not active at night, in water or on land. However, we observed nesting activity at night despite minimal monitoring at night. The female mentioned above may have crossed the highway at night, when traffic volume decreased. The highway may act as a selective force, selecting for turtles that move at night or during hours of lighter traffic.

Management Implications

Traffic and road densities are increasing worldwide (UN 1992), and efforts to mitigate roadkill mortality and habitat fragmentation by roads will be essential to sustaining some wildlife populations, especially reptiles and amphibians (see Mader 1984, Doroff and Keith 1990, Reh and Seitz 1990, Rosen and Lowe 1994, Bull 1995, Fahrig et al. 1995).

Increasing Permeability of Roads

The most effective method for increasing permeability of roads is to elevate (bridge), thereby removing the barrier (De Santo 1993). Other methods proven to mitigate roadkills include narrowing the road width (Oxley et al. 1974, Mader 1984) and reducing the traffic speed and volume (van Gelder 1973, Rosen and Lowe 1994, Fahrig et al. 1995). In addition, several studies have shown that culverts, drift fences, and pitfall traps can decrease roadkill mortality for various vertebrates (Gibbons 1970, Hunt et al. 1987, Tyning 1989, Bush et al. 1991, De Santo 1993, Krivda 1993, Ruby et al. 1994, Fahrig et al. 1995, Yanes et al. 1995, among others). These methods can be modified to work for painted turtles and other species vulnerable to Highway 93 traffic.

Because culverts and other road-crossing mechanisms have been minimally examined for freshwater turtles, designs should be tested on Highway 93 before their permanent construction. This will also help mitigate roadkill mortality in the short term. Yanes et al.'s (1995) methods involved using tracks to determine which animals are using the culverts and their willingness to do so (see Yanes et al. 1995). They found that reptiles were willing to use culverts under railway lines but not under roadways. Yanes et al. (1995) found that small mammals' and carnivores' willingness to use culverts decreased with increased length of the culvert. Although they did not test this for reptiles, they found that willingness to use a culvert generally depended on the length of the culvert (e.g. the width of the road) and the home range of the animal (e.g. animals with smaller home ranges are less likely to use longer culverts). Future monitoring of painted turtle movements may indicate the lengths of culverts they are willing to pass through. Ruby et al. (1994) found little reluctance among desert tortoises (*Gopherus agassizi*) to pass through tunnels and culverts, but this is a burrowing animal.

An additional feature that is important to test is the painted turtle's need for ambient light in culverts. Painted turtles are diurnal animals, for the most part, and may use the sun for navigation (DeRosa and Taylor 1978). Therefore, mechanisms to allow ambient light in the culverts/tunnels may be necessary to their success for this species (see Langton 1987). Grates over the top of a culvert or section of culvert will allow light to pass through, but there may be a tradeoff with the increased noise from traffic due to the opening. Again, these mechanisms should be tested for painted turtles and other species in western Montana.

Funnelling turtles into culverts will be necessary to increase the probability that they use the underpass rather than cross the road (Yanes et al. 1995). Turtles DOR were found on sections of Highway 93 that bridge over water (Crow Creek) or contain a large culvert for allowing water to pass through (into Ninepipe Reservoir), showing that they do not necessarily choose the aquatic route under the road. Ruby et al. (1994) studied drift fence materials and their use in directing desert tortoises. From several trials involving tortoises enclosed by these different materials, they recommended hardware cloth first, and solid materials second. Painted turtles could climb the hardware cloth, so a solid barrier would be most effective for funnelling them. Another advantage of a solid barrier is that turtles are less likely to try to poke through and get stuck (Ruby et al. 1994). A solid drift fence can act as an audio and visual barrier as well, decreasing an animal's stress level caused by traffic (De Santo 1993).

Future Monitoring

Informed management decisions for turtles depend on an understanding of their movements and habitat use patterns (Gibbons 1970, Gibbons 1986). Monitoring movement patterns will help managers understand which turtles are crossing the highway and other roads and suggest why they are choosing that route. The distance turtles are willing to travel will indicate whether turtles are travelling to ponds next to the highway, which are possible population sinks (see Rosen and Lowe 1994). With such a network of thousands of pothole wetlands, the population throughout the region may be made up of as many subpopulations. Such a "metapopulation" depends on immigration and emigration between ponds to maintain genetic variability in each subpopulation and to allow recolonization after local extinctions. Understanding metapopulation dynamics of freshwater turtles may require long term study and large sample sizes (*****need to add citation here). Monitoring genetic variability and population trends also could indicate whether secondary roads and/or agricultural practices are contributing to habitat fragmentation (see Mader 1984, Dodd 1983, Doroff and Keith 1990).

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