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Painted turtle in the Mission Valley of western Montana

Suzanne C. Fowle
The University of Montana

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THE PAINTED TURTLE IN THE MISSION VALLEY OF WESTERN MONTANA

By

Suzanne C. Fowle

B.A. Brown University, 1990

Presented in partial fulfillment of the requirements for the degree of

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Approved by:

Daniel H

Chairperson

Dean, Graduate School

7-30-96

Date

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I monitored a population of painted turtles in the Mission Valley's prairie pothole region from May to August 1995. I trapped turtles with basking traps, funnel traps, dip nets, and seine nets in 16 permanent and 7 temporary pothole wetlands. Road-killed turtles were collected along a 7.2 km section of US Highway 93 adjacent to the Ninepipe National Wildlife Refuge. Additional information was gathered from turtles dead on secondary roads in the area. Femurs were removed from each dead on the road (DOR) turtle for laboratory age determination (sectioning at Matson's Lab, Milltown, MT).

I found that males reach sexual maturity at 93 mm plastron length, and females at 166 mm plastron length. The nesting season lasted from 31 May to 12 July, and average clutch size was 9.8 (SD=3.9). Sex ratios varied by pond, although the overall ratio was 1.9:1 (males to females). I developed an age-predicting regression model using the relationship between shell measurements and ages determined by counting annuli on femur cross sections from road-killed turtles. The regression models were based on the shell measurements most highly correlated with age: plastron width for adult males ($R^2=0.80$, $P<0.01$, $n=30$); plastron width for adult females ($R^2=0.50$, $P=0.01$, $n=13$); and plastron length for juveniles ($R^2=0.94$, $P<0.01$, $n=20$). Plastron length was more powerful than number of shell annuli as a predictor of juvenile age. Turtles >18 years old were the most variable in size.

In response to local concern about intense turtle mortality on US Highway 93, I examined the effects of roadkill mortality on the Mission Valley turtle population. Turtle mortalities spanned the monitored section of US 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 ($\bar{x}=10.1$, SD=6.3, $n=125$). 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 females). I found that ponds farther from the road consisted of higher percentages of adult turtles (>12 years old) than ponds adjacent to the road. In addition, I estimated population densities in these ponds and found that population density increases with distance from the highway ($R^2=0.57$, $P=0.03$). Growth rates were significantly higher in ponds adjacent to the highway (F ratio=28.6, $P<0.01$), possibly in response to decreased population density. Management recommendations were suggested based on roadkill data and literature review.

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INTRODUCTION

The painted turtle (*Chrysemys picta bellii*) is the only turtle species native to western Montana. The common snapping (*Chelydra serpentina*) and spiny softshell (*Trionyx spiniferus*) turtles occur east of the Continental Divide. No documented studies exist for any turtle population in Montana. Because declines in turtle populations -- and populations of other long-lived organisms with delayed onset of sexual maturity -- often go undetected until recovery is difficult, careful monitoring is essential to their conservation. Due to life history strategies characteristic of long-lived, iteroparous organisms, turtle population stability is easily disrupted by increased mortality, especially of adults and older juveniles.

This project was initiated by public concern for road-killed painted turtles on the Flathead Indian Reservation in western Montana. The acute level of concern was especially apparent at several public scoping meetings held to solicit comments on a Montana Department of Transportation proposal to widen US Highway 93, which runs north-south through the Reservation.

Chapter 3 directly addresses the issue of conservation of painted turtles in the Mission Valley of the Flathead Indian Reservation, while Chapters 1 and 2 provide baseline information and an aging technique necessary for future monitoring and investigation. Specifically, Chapter 1 describes life history traits of the Mission Valley painted turtle population. Chapter 2 provides a model for predicting turtle ages, and Chapter 3 discusses the effects of roadkill mortality on the Mission Valley population.

CHAPTER I

DESCRIPTION OF LIFE HISTORY TRAITS

INTRODUCTION

Several authors have examined life history traits of western painted turtles (*Chrysemys picta bellii*) and geographic variation among populations (Christiansen and Moll 1973, Hart 1982, MacCulloch and Secoy 1983, Lindeman 1988, Frazer et al. 1991, Frazer et al. 1993, Iverson and Smith 1993, St. Clair et al. 1994, Lindeman 1996). These authors suggested that variation is due to differences in latitude, elevation, diet, and length and average temperature of growing seasons. For example, increased sizes and ages of sexual maturity at northern latitudes, where the growing season is too short to allow more than one clutch per year, result in larger clutch sizes (Christiansen and Moll 1973, Hart 1982, MacCulloch and Secoy 1983, St. Clair et al. 1994). Because painted turtle populations can vary so widely, these traits cannot be projected from one population onto another, even within the same subspecies (Gibbons 1990a).

Life history characteristics of painted turtles have never been documented in western Montana's Mission Valley (near the northern edge of the western painted turtle's range). Geographically, the closest population studied was in northwest Idaho (Lindeman 1988, Lindeman 1996). I examined data from the Mission Valley turtle population to estimate population parameters and compare them to other studies. I examined whether average clutch size and age/size at sexual maturity correlate with latitudinal predictions, i.e. whether these traits for a western Montana population fit into the latitudinal gradient suggested by other studies. I also documented the onset and termination of the nesting season and the sex ratios in various ponds in the Mission Valley. I estimated these parameters from road-killed painted turtles, live turtles trapped in the Valley's pothole wetlands, and anecdotal observations. The information provided contributes to future monitoring of this population, especially important in light of the number of turtles killed on the highway.

Study Area

I examined a population of painted turtles in the Mission Valley, on the Flathead Indian Reservation, in western Montana. Although surrounded by mountains (the Mission Range) and buttes (the Moiese Hills), the valley floor resembles the prairie pothole region of the Dakotas and central Canada. One section of the valley, near Ninepipe National Wildlife Refuge, consists of an especially high concentration of over 2,000 pothole wetlands in a 30 mi^2 (77.8 km^2) area. US Highway 93 bisects this network of ponds along a 4.5 mi (7.2 km) stretch. Both the potholes and the road itself made up the study area; live turtles were trapped in the ponds, and road-killed turtles were collected. A 13.5 mi^2 (17.3 km^2) area of the concentrated pothole region was examined, in the middle of which passed Highway 93 (see Figure 3.1, Chapter 2). However, dead turtle specimens were collected anywhere in the pothole region and were not restricted to the area of highly concentrated wetlands.

METHODS

Data collection occurred from 17 May to 24 August, 1995. We collected DOR turtles on the Highway 3 mornings per week. (A thorough description of recording roadkill locations is in Chapter 3.) We also collected any other dead turtles found in the pothole region, including those found on secondary roads and a group of 15 turtles that had been shot in 2 potholes next to Kicking Horse Dam. We determined the sex of each specimen, took 5 measurements on the shell (if it was sufficiently intact), and collected a femur for age estimation (by Matson's Lab, Milltown, Mont.). The shell measurements were taken to develop an age-predicting model based on the relationship between turtle size and lab-estimated age (see Chapter 2). Turtles were aged by counting growth annuli on cross sections of the femurs, assuming an October birthday for all turtles.

With these data, I could estimate the age/size of female sexual maturity for the Mission Valley population. I used the age of the youngest gravid female found as an estimate of age of sexual maturity. I considered one DOR female without eggs as a gravid female because she had recently finished nesting, as indicated by the mud caked on her posterior carapace (Legler 1954, Tinkle et al. 1981). I used plastron length and width to estimate size of females at sexual maturity.

I determined the average clutch size for this population of painted turtles by examining females found DOR because I was usually able to count the number of eggs. (If the eggs had been destroyed by traffic or predators, I could only detect the presence of eggshells and yolks.) I also counted the number of eggs laid by a nesting female and the number of eggs found in a gravid female that had been shot. I estimated the end of the nesting season by the day we found the last gravid DOR female. The beginning of the nesting season was estimated from the first female observed attempting to nest.

We trapped live turtles in 16 permanent ponds mostly using basking traps, which were left in the ponds throughout the field season and usually checked every 2 days. We supplemented the basking traps with funnel traps, dip nets, and seine nets when possible (see Chapter 2). We sexed each turtle captured and took the same 5 measurements on the shells that we took on the dead specimens.

I estimated the age and size of males at sexual maturity from captured turtles. Male painted turtles develop secondary sex characteristics (elongated foreclaws and elongated preanal region of the tail) just before they reach sexual maturity (Frazer et al. 1993). Juvenile turtles could not be sexed because they were not sexually dimorphic before males developed these characteristics. The youngest male with secondary sex characteristics was taken from a sample of 640 male turtles trapped, and ages were predicted by the model developed from this study (see Chapter 2). Minimum size (plastron length and plastron width) of sexually mature males was estimated in the same way, consistent with MacCulloch and Secoy (1983).

I also estimated the sex ratio in each pond from trapping data. Because 77% of all turtle captures (n=1,048, not including recaptured turtles) were in basking traps, and most of the ponds were sampled only with this method, I first tested whether the basking traps were biased for one sex. Assuming dip nets and seine nets captured an accurate ratio of males to females, I compared the sex ratios of turtles caught in seine nets and dip nets to the ratio of turtles caught in the basking traps. In Pond 365, we caught 32 adult turtles in dip nets and 50 in basking traps, so I used this pond to compare sex ratios of these two capture techniques. I compared basking trap and seine net sex ratios using data from Pond 345, in which we captured 27 adults in seine nets and 121 adults in basking traps. I also compared the sex ratios of adults caught in funnel traps to that of basking traps in Pond 886, in which we captured 16 adult turtles in funnels and 29 in basking traps.

RESULTS

Age and Size at Sexual Maturity

Gravid female ages ranged from 7 to 17 (Table 1.1). However, the 7 year old was not the smallest gravid female. The smallest gravid female in plastron length was 166 mm, and the smallest in plastron width was 82 mm (Table 1.1). According to femur annuli counts, these turtles were 11 and 9 years old respectively. The youngest males with secondary sex characteristics were 2 years old. The minimum plastron length was 93 mm, measured on a 4 year old, and the minimum plastron width was 49 mm, measured on a 3 year old.

Nesting Season and Average Clutch Size

The nesting season started on 31 May, when the first female was observed digging a nest. It extended through 12 July, when the last gravid female was found DOR. The average clutch size for painted turtles in the Mission Valley was 9.8 (SD=3.9, n=8). Clutch sizes ranged from 6 to 18 (Table 1.1).

Sex Ratios and Evaluation of Trapping Techniques

The sex ratio of turtles caught in basking traps was similar to that of turtles caught in dip nets and seine nets. The comparison of dip net to basking trap sex ratios (1.5:1 versus 1.8:1, males to females) was not significant (Pond 365, Pearson value=0.18, P=0.67, n=82), nor was the comparison with the seine net sex ratio (Pond 345, 4.4:1 in basking versus 3.3:1 in seines, Pearson value=0.27, P=0.60, n=148). The sex ratios in basking traps (1.4:1) and funnel traps (3:1) also did not differ significantly (Pond 886; Pearson value=1.21, P=0.27, n=45). Therefore, I pooled adult turtles caught in all trap types to calculate sex ratios for each pond. The sex ratios varied among the 16 ponds sampled (Table 1.2). The overall sex ratio was 1.9:1 (males to females) when the sex ratios of all ponds were pooled together.

Table 1.1. Ages, plastron lengths, and clutch sizes ($\bar{x}$=9.8, SD=3.9) of gravid female painted turtles from the Mission Valley study area.

Age	Plastron width (mm)	Plastron length (mm)	Clutch size
7	91	187	12
9	82	unk	unk
9	87	187	9
10	88	181	8
11	unk	166	unk[a]
11	unk	176	unk
13	93	185	18
14	85	176	6
14	91	186	unk
15	unk	203	9
17	unk	unk	10
unk[b]	unk	182	6

a=returning from nesting, no eggs
b=observed nestin

Table 1.2. Sex ratios of adult turtles from permanent ponds sampled and found DOR in the Mission Valley.

Pond no.	DOR	72	168	345	365	613	621	839	877	886	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

DISCUSSION

Age and Size at Sexual Maturity

The youngest roadkill gravid female (7 years old) was a reasonable estimate of age of sexual maturity; this age is consistent with results from other western painted turtle studies (Legler 1954, Christiansen and Moll 1973, MacCulloch and Secoy 1983, Iverson and Smith 1993, Lindeman 1996). The female age of sexual maturity may have been younger than 7 and still remained consistent with other populations (5 to 10 years old, Table 1.3), however, my data could neither confirm nor disprove this.

The gravid females with the smallest plastron width (82 mm) and length (166 mm) were 9 and 11 years old. Size rather than age may determine the point at which female painted turtles reach sexual maturity (Cagle 1954, Gibbons 1968, MacCulloch and Secoy 1983, Christens and Bider 1987, Iverson and Smith 1993, Lindeman 1996). Lindeman (1996) compared 2 ponds in Idaho and Washington (at similar latitudes) with different growth rates. He found that males and females in both ponds reached sexual maturity at similar sizes, but the turtles in the pond with the faster growth rate reached these sizes at earlier ages. Therefore, the estimate for female age of sexual maturity in the Mission Valley may be high. Since the youngest gravid female (7 years old) was not the smallest, she probably reached sexual maturity at age 5 or 6. Body size and clutch size have been shown to be positively correlated (MacCulloch and Secoy 1983, Schwartzkopf and Brooks 1986, Lindeman 1988, Gibbons and Greene 1990, Iverson and Smith 1993, St.Clair et al. 1994, Lindeman 1996), so size may be more important than age to a female's ability to reproduce.

Size and age of sexual maturity may also be positively correlated with latitude and elevation (Christiansen and Moll 1973, Hart 1982, MacCulloch and Secoy 1983, Lindeman 1988, St. Clair et al. 1994). Christiansen and Moll (1973) found that turtles grow faster at northern latitudes and reach sexual maturity later and at larger sizes than at southern latitudes. According to this trend, Mission Valley estimates of female age/size of sexual maturity are slightly high (Table 1.3).

The earliest we found a 2 year old male with secondary sex characteristics was on 23 July, indicating that 2 year old males probably show signs of incipient sexual maturity and actually become sexually mature at age 3 (Gibbons and Greene 1990, Frazer et al. 1993). The Mission Valley estimate for male age at sexual maturity is low for its latitude and elevation, however, male size at sexual maturity (93 mm plastron length) is within the range of sizes reported in the literature (Table 1.4). Frazer et al. (1993) found that male painted turtles matured one year earlier in the late 1980s than in the early 1980s (attributing this to warmer annual temperatures in the late 1980s) while the size at sexual maturity remained constant. Lindeman (1996) also found sexual maturity to be size, rather than age, dependent. Mission Valley turtles therefore may be growing at faster rates than others at similar latitudes and reaching size at sexual maturity earlier (Frazer et al. 1993, Lindeman 1996). Recent growing seasons in the Mission Valley may have been significantly longer and/or warmer, causing an increase in growth rate and subsequent early sexual maturity (Frazer et al. 1993). This phenomenon would also apply to females because most painted turtle studies suggest that female sexual maturity is size-dependent

Table 1.3. Latitudinal and elevational comparison of western painted turtle populations: average clutch sizes and minimum ages and sizes of sexually mature females.

Age	Plastron length (mm)	Average clutch size	Location, latitude, and elevation (m)	Reference
5-6	132	9.0 (n=46)	New Mexico 34.0 1120	Christiansen & Moll 1973
5	148	13.9 (n=221)	Nebraska 42.0 1165	Iverson & Smith 1993
unk	160	8.8 (n=13)	Minnesota 44.5 310	Legler 1954
7	136[a]	10.2 (n=28)	Wisconsin 45.0 420	Christiansen & Moll 1973
7-8	160	15.8 (n=20)	Idaho 46.5 790	Lindeman 1996
7	166[a]	9.8 (n=8)	Montana 47.5 946	this study
9-10	160	13.4 (n=10)	Washington 47.5 700	Lindeman 1996
unk	150	19.8 (n=5)	Saskatchewan 50.5 570	MacCulloch & Secoy 1983

Age=youngest sexually mature female; Plastron Length (PL)=smallest mature female; Average Clutch Size (CS)=mean clutch size for the population, indicated with sample size; a=minimum age and minimum PL not from the same turtle. All of the authors listed determined minimum age of sexual maturity by counting annuli on the plastron, except for this study where we used annuli counts from the femur.

Table 1.4. Minimum ages and sizes of sexually mature male painted turtles.

Age	Plastron length (mm)	Location	Reference
unk	65	Louisiana[a]	Hart 1982
3	88	New Mexico	Christiansen and Moll 1973
4-6	75	Michigan	Frazer et al. 1993
4-5	96-100	Wisconsin	Christiansen and Moll 1973
3	93	Montana	this study
unk	100	Manitoba[a]	Hart 1982

a=not western subspecies

(Cagle 1954, Gibbons 1968, MacCulloch and Secoy 1983, Christens and Bider 1987, Iverson and Smith 1993, Lindeman 1996). This is consistent with Caswell's (1983) and Stearns and Koella's (1986) conclusions that phenotypic plasticity in life history traits is advantageous in the face of environmental variability.

Plastron width may be a better measure of female size at sexual maturity than plastron length. I found that width was more highly correlated with age (see Chapter 2). However, all other studies used plastron length to discuss size at sexual maturity, so I used length to compare Mission Valley turtles to other populations. In developing the age-predicting model for males (Chapter 2), I found plastron width to be only slightly more highly correlated with age than length was with age, so I was able to clearly compare male size at sexual maturity to other studies, all of which used plastron length.

Average Clutch Size

Painted turtle clutch sizes increase with latitude and elevation (Christiansen and Moll 1973, MacCulloch and Secoy 1983, Lindeman 1988, Iverson and Smith 1993). MacCulloch and Secoy (1983) calculated a mean clutch size of 19.8 for a painted turtle population in southern Saskatchewan. They concluded that larger clutch sizes in northern latitudes may occur to compensate for the shorter growing season, which precludes multiple clutches (Christiansen and Moll 1973). Christiansen and Moll (1973) compared populations in Wisconsin and New Mexico and found a larger mean clutch size in Wisconsin, although the difference was not significant. Lindeman (1988) developed a linear model for predicting average clutch size from latitude and elevation. For Flathead

County, Montana, adjacent to and north of the Mission Valley (Lake County), Lindeman predicted an average clutch size of 17.0, considerably higher than our observed average clutch size of 9.8.

With an average clutch size of 9.8 (SD=3.9), the Mission Valley population of painted turtles is more similar to populations monitored in Wisconsin and New Mexico where Christiansen and Moll (1973) found average clutch sizes of 10.2 and 9.0, respectively (Table 1.3). Mean clutch size in the Mission Valley is smaller than those found in western Nebraska ($\bar{x}$=13.9, Iverson and Smith 1993), southern Saskatchewan ($\bar{x}$=19.8, MacCulloch and Secoy 1983), and Idaho ($\bar{x}$=15.3, Lindeman 1988) (Table 1.3). My sample size of 8 may not have been large enough to accurately estimate average clutch size. In addition, other factors that play a part in average clutch size, such as length and average temperature of growing season, and degree of carnivory (MacCulloch and Secoy 1983, Lindeman 1996), were not measured in the Mission Valley. Further investigation of these variables will help explain geographic variation in clutch size.

Nesting Season

Nesting occurred from 31 May to 12 July in the Mission Valley. Although the female that was observed attempting to dig a nest on 31 May did not lay her eggs, I assumed this date was the best estimate because human interference may have been the only reason why she did not continue nesting. My estimate of nesting season for the painted turtle population in the Mission Valley (May 31 to July 12) roughly correlates with those found in other studies. Lindeman (1988) found a combined nesting season lasting from 29 May to 1 July in 2 populations of western painted turtles in Washington and Oregon. Iverson and Smith (1993) reported a nesting season occurring from 19 May to 17 July in western Nebraska.

Sex Ratios

Gibbons (1990b) cautioned that sex ratios of freshwater turtle populations vary from population to population, and they vary within the same population, depending on the time of year and the recorders' consistency in distinguishing between adult females and juveniles (both of which lack male secondary sex characteristics). The results from the Mission Valley confirm the variability in sex ratios among freshwater turtle populations because the ratios ranged from 0.9:1 to 5.1:1 (males to females) in the ponds sampled (Table 1.2).

CONCLUSION

Because turtle populations are extremely sensitive to increases in mortality (Doroff and Kieth 1980, Brooks et al. 1991, Dodd 1983, Congdon et al. 1993, Congdon et al. 1994, Garber and Burger 1995), further investigation into their life history traits is essential to their conservation. My results provided baseline information about the Mission Valley population's life history traits, however, future monitoring is necessary to document characteristics that can help explain population dynamics and population trends. For example, an understanding of reproductive rates requires study of nest success, clutch frequency, and proportion of females breeding each year as well as further investigation into average clutch size. In addition, documentation of life history traits of turtles in the Mission Valley will contribute to describing geographic variation among turtle populations and separating that from environmental causes of variation.

CHAPTER II

A MODEL FOR PREDICTING TURTLE AGES FROM SHELL MEASUREMENTS

INTRODUCTION

Estimating the ages of turtles is essential to examination of population parameters and trends. The best method for aging painted turtles is long-term monitoring of known-age turtles (e.g. those with known hatch years) (Dunham and Gibbons 1990, Zug 1991), however, their longevity makes this difficult. More expedient methods may be necessary to detect declines in some populations before recovery becomes difficult or impossible because such long-lived organisms are extremely vulnerable to mortality increases (Doroff and Keith 1990, Brooks et al. 1991, Congdon et al. 1993, Congdon et al. 1994). Several authors have suggested that adult and juvenile survival are far more important to turtle population stability than nest success or hatchling survival and these rates may have to be substantially higher for turtles than for many other vertebrates (Crouse et al. 1987, Congdon et al. 1993, Congdon et al. 1994, Cunnington and Brooks 1996). Estimation of survival rates requires age- or stage-determination.

Painted turtles exhibit growth annuli on their shells, but older annuli wear off as a result of ecdysis, and turtles older than 5 cannot be reliably aged this way (Sexton 1959, Lindeman 1988, Dunham and Gibbons 1990, Zug 1991). Several other methods have been attempted for aging turtles: von Bertalanffy growth curves (Frazer et al. 1991), logarithmic and linear age-size relationships (Gibbons 1968, Wilbur 1975b), age-annuli length relationships (Sexton 1959), and skeletochronology (Hammer 1969, MacCulloch and Secoy 1983, Zug et al. 1986). All of these methods are complicated by highly variable growth rates. Environmental sources of variation that have been documented for Emydid turtles include degree of carnivory and nutrients in the diet (Gibbons 1967, Knight and Gibbons 1968, MacCulloch and Secoy 1983, Lindeman 1988 and 1996), average temperature and length of the growing season (Frazer et al. 1991 and 1993), population density (Gibbons 1967, Wilbur 1975b, Dunham 1980, Hart 1982, MacCulloch and Secoy 1983, Dunham and Gibbons 1990), and water and basking temperatures (MacCulloch and Secoy 1983). Emydid turtle growth rates also vary by sex (Cagle 1946, MacCulloch and Secoy 1983, Dunham and Gibbons 1990, Mitchell and Pague 1990) and age (Cagle 1946, Sexton 1959, Wilbur 1975b, MacCulloch and Secoy 1983, Dunham and Gibbons 1990, Mitchell and Pague 1990) within populations and by latitude and elevation between populations (Hart 1982, MacCulloch and Secoy 1983, Lindeman 1988, St. Clair et al. 1994, Lindeman 1996). Because these factors affect populations differently and vary temporally, these methods and models cannot be easily applied to turtles outside of the population or time period on which they were based.

Several authors have found skeletochronology to be a reliable estimate of reptile and amphibian ages: MacCulloch and Secoy (1983) for western painted turtles; Hammer (1969) for snapping turtles (*Chelydra serpentina*); Zug et al. (1986) for loggerhead sea turtles (*Caretta caretta*); and Russell et al. (1996) for long-toed salamanders (*Ambystoma* *macrodactylum krausei*). I used skeletochronology to develop a size-based model for predicting painted turtle ages because I had access to over 200 road-killed turtles in western Montana, where temperate climate ensures clear growth rings in the cross sections of long bones (Zug 1991). (US Highway 93 is a 2-lane federal highway that has been a recent topic of public concern due to the number of painted turtles killed while attempting to cross. See Chapter 3). I used femurs from these turtles to estimate their ages and tested the age-predicting power of various straight-line measurements taken on the specimens' shells.

Study Area

I examined a population of turtles on the Flathead Indian Reservation of western Montana. Turtles inhabit a network of highly-concentrated pothole wetlands on the floor of the Mission Valley, in the central section of the Reservation. I collected femurs from turtles found dead on US Highway 93, a 4.5 mi (7.2 km) section of which bisects the Valley's pothole area, and on secondary roads in the region. More detailed descriptions of the pothole region are in Chapters 1 and 3.

METHODS

Femur Collection and Aging

We collected road-killed turtles 3 mornings per week from 17 May to 24 August, 1995, along Highway 93. We sexed each specimen (see "Methods," Chapter 3), removed a femur, counted the number of annuli visible on the plastron, and took 5 measurements on the shell. The 5 measurements included: carapace length, plastron length, plastron width, plastron "height," and length of the most recent annulus on the right abdominal lamina (Figure 2.1). All of these measurements were straight-line lengths, measured with calipers to the nearest 0.05 mm. The number of annuli was the maximum number of annuli we could see on any one lamina of the plastron. Many of the turtles found dead on the road (DOR) were not sufficiently intact to collect all measurements.

Matson's Laboratory (Milltown, Mont.) estimated the ages of DOR turtles from cross sections of the femurs. Bone annuli were counted under the following assumptions (G. Matson, Matson's Laboratory Director, pers. commun.): all turtles hatched in October; annuli formed during the winter; and the first annulus, broadly spaced from the resorption core, represents the second winter of life and an age of 1 year and 3-5 months. Turtle ages were recorded with 3 categories of certainty, ranging from Level A, ±0 years, to Level C, ±4 years, and varying according to the age of the turtle (Table 2.1). These levels were determined by evidence of resorption of early annuli, signs of bone damage, and distinctiveness of growth layers (G. Matson, pers. commun.).

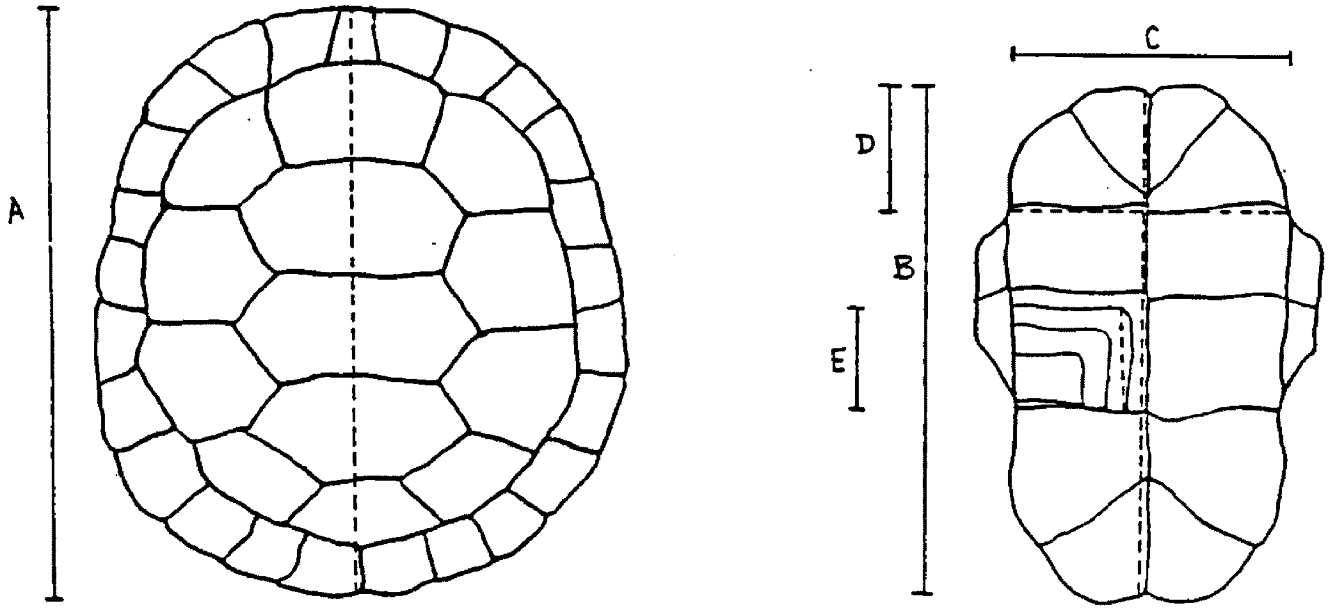


Figure 2.1 Illustration of shell measurements: a) carapace length; b) plastron length; c) plastron width; d) plastron height; e) annulus length.

Table 2.1. Levels of certainty subjectively applied to each femur annuli count by Matson's Laboratory (Milltown, Mont.).

	Certainty code (years)		
Determined turtle age (years)	A	B	C
1-7	±0	±1	±2
8-15	±1	±2	±3
16+	±2	±3	±4

Age-Size Regression Analysis

Although Emydid juveniles of both sexes appear to grow at similar rates, adult growth slows when sexual maturity is reached (Gibbons 1968, Hart 1982, MacCulloch and Secoy 1983, Dunham and Gibbons 1990, Mitchell and Pague 1990, Frazer et al. 1993). The rates and sizes/ages at which growth slows are different for males and females (Hart 1982, MacCulloch and Secoy 1983). Therefore, I analyzed age-size relationships separately for adult males, adult females, and juveniles. The adult male model was based on males >93 mm in plastron length, and the female model was based on turtles >160 mm in plastron length, consistent with Lindeman (1996), because these are approximate sizes at sexual maturity (see Chapter 1), at which point growth slows (Wilbur 1975b, Hart 1982, MacCulloch and Secoy 1983). All turtles that were sexed as juveniles, as well as males and females younger than these ages, were entered into the juvenile model. I linearized the data using a natural log transformation on both the dependent (age) and independent (measurements) variables to achieve homogeneity of variance. Because some juveniles were age 0, I transformed juvenile age by taking the natural log of (age + 1).

I used SPSS software to perform a backward regression (Model II) using 3 independent variables: plastron length (PL), plastron width (PW), and the product of PL and PW. These were more highly correlated with age than any other straight-line measurements and ratios of the measurements (e.g. carapace length to plastron length). Because older turtles (>18 years old) tended to be smaller in all measurements, I based the adult models on turtles less than 18 years old. This allowed greater accuracy overall, but increased the degree to which older turtle ages were underestimated. Because the model was based on size, these smaller, older turtle ages would be underestimated regardless of the ages chosen for building the model (Figure 2.4a).

Regression analysis to determine which shell measurement was the most powerful predictor of age resulted in different measurements selected for adults and juveniles, so I based each model on the measurement that was most highly correlated with age (Table 2.2). For juvenile turtles, I also included the number of shell annuli in the independent variables to test whether number of annuli was a better predictor of age than any of the shell measurements. Shell annuli were not tested for adult painted turtles because they lose their plastral annuli due to ecdysis. I also examined the correlation between number of bone annuli (e.g. the age determined by the Lab) and the number of shell annuli in juveniles to determine whether the 2 methods produced the same age estimates.

RESULTS

Reliability of Femur Aging Method

Out of 181 femurs aged, 81% of the estimates were determined at reliability Level A, 18% at Level B, and 2% at Level C. For juveniles, number of shell annuli and age were significantly correlated (Spearman correlation=0.84, $P<0.01$, n=23). However, only 37% of the age estimates exactly equaled the number of shell annuli counted (n=43) (Figure 2.2).

Age-Size Regression Analysis

Plastron width (PW) and plastron length (PL) were both significantly correlated with adult male age (Pearson correlation=0.90 and 0.89 respectively, both $P<0.01$, n=28). PW was the independent variable used in the final model because the correlation was slightly higher (Table 2.2). The predictive equation was ($R^2=0.80$, $P<0.01$, n=30):

$$\text{adult } \male \text{ age} = e^{[-11.61 + (3.24 * \ln(PW))]}$$

Adult females showed the greatest difference in correlation between age and the 2 plastron measurements; PW was significantly correlated (Pearson correlation= 0.62, P=0.01, n=13) whereas PL was not significantly correlated at the 0.05 level (Pearson correlation=0.38, P=0.09, n=13). Although the relationship was significant, adult females showed the lowest percent (50%) of variance in age explained by size ($R^2=0.50$, P=0.01, n=13) (Table 2.2). The equation for predicting adult female age was:

$$\text{adult } \female \text{ age} = e^{[-7.59 + (2.25 \bullet \ln(PW))]}$$

The juvenile model had greater predictive power than either of the adult models ($R^2=0.94$, $P<0.01$, n=20) (Table 2.2). PL was most highly correlated with juvenile age (Pearson correlation=0.98, $P<0.01$, n=18), although PW was also significantly correlated with age (Pearson correlation=0.95, $P<0.01$, n=18). The regression model was based on PL (Figure 2.3b), using the following equation:

$$\text{juvenile age} = e^{[-5.10 + (1.41 \bullet \ln(PL))]} - 1$$

I compared the correlation between juvenile age and PL to the correlation between juvenile age and number of shell annuli. Although they were both significant, PL was more closely correlated with age, indicating that it may be a more powerful predictor of juvenile age (PL Pearson correlation=0.97, shell annuli Pearson correlation= 0.80, both $P<0.01$, n=15).

Variation in Growth Rates

Turtle growth rates varied within the population, especially among older turtles (>18 years old). The plastron widths and lengths of different-aged turtles overlapped (Figures 2.3a and 2.3b) In addition, average size varied by pond (Figure 3.7).

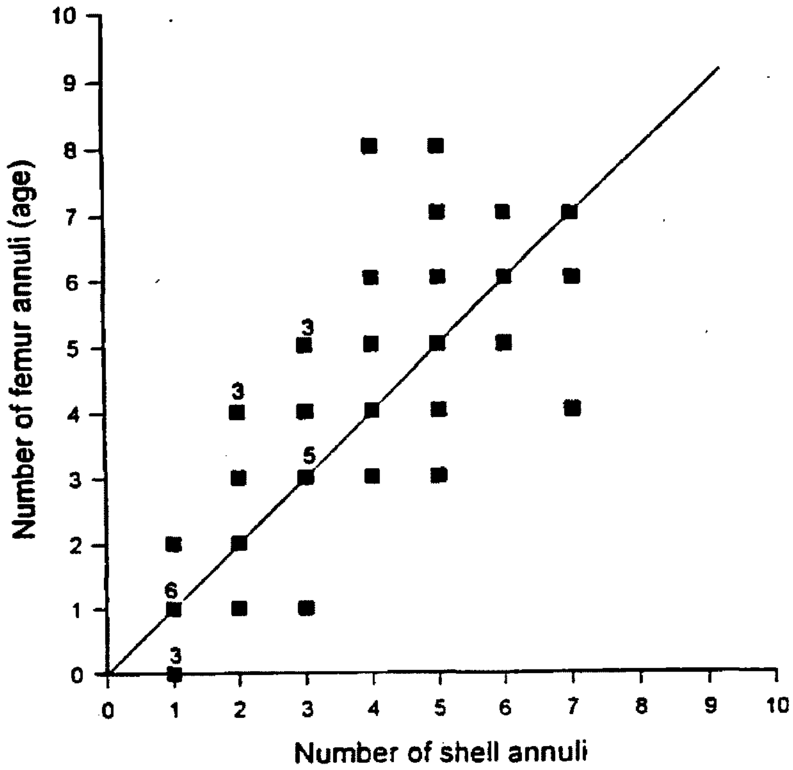


Figure 2.2. Comparison of shell and femur annuli counts taken from turtles found DOR in the Mission Valley (all turtles with <10 femur annuli). Numbers above points represent samples >1.

Table 2.2. Summarized results of regression model for predicting turtle ages from shell measurements.

Group	Plastral measurement[a]	R square	F significance
juveniles	length	0.94	0.000
adult males	width	0.80	0.000
adult females	width	0.50	0.007

a=measurement found to be most highly correlated with age.

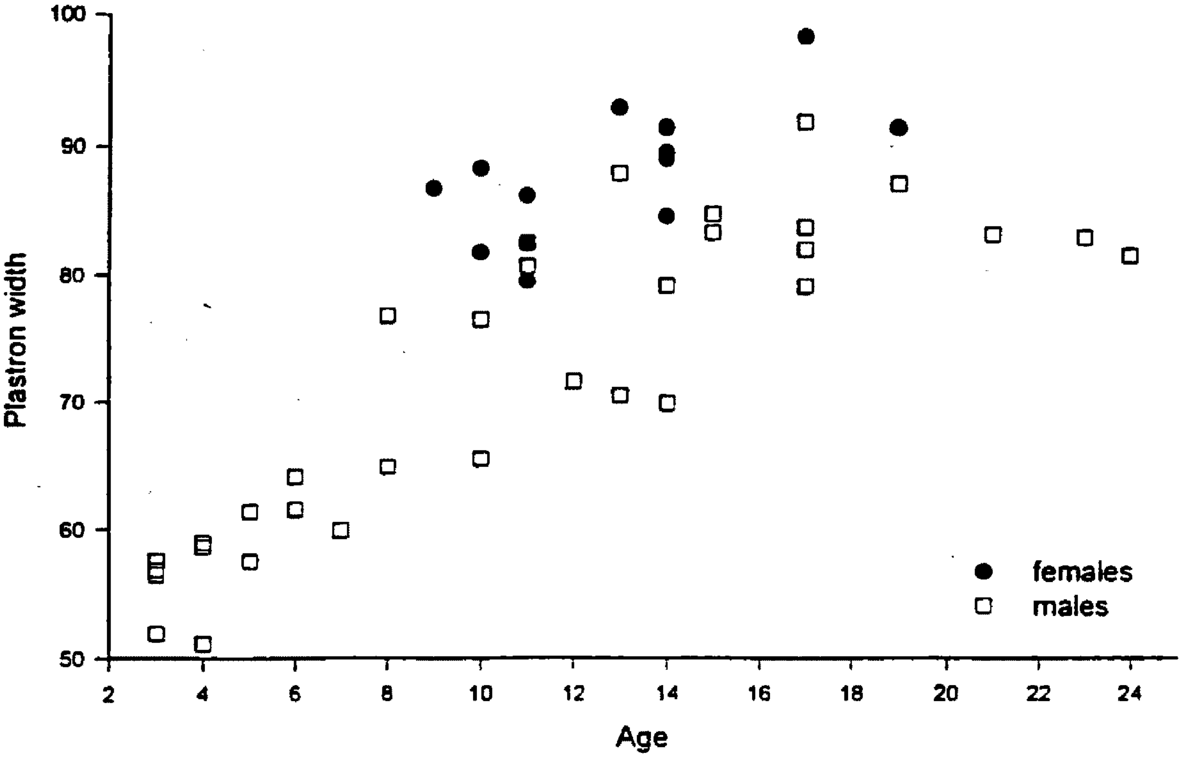


Figure 2.3a. Plastron width by age of adult male and female turtles in the Mission Valley.

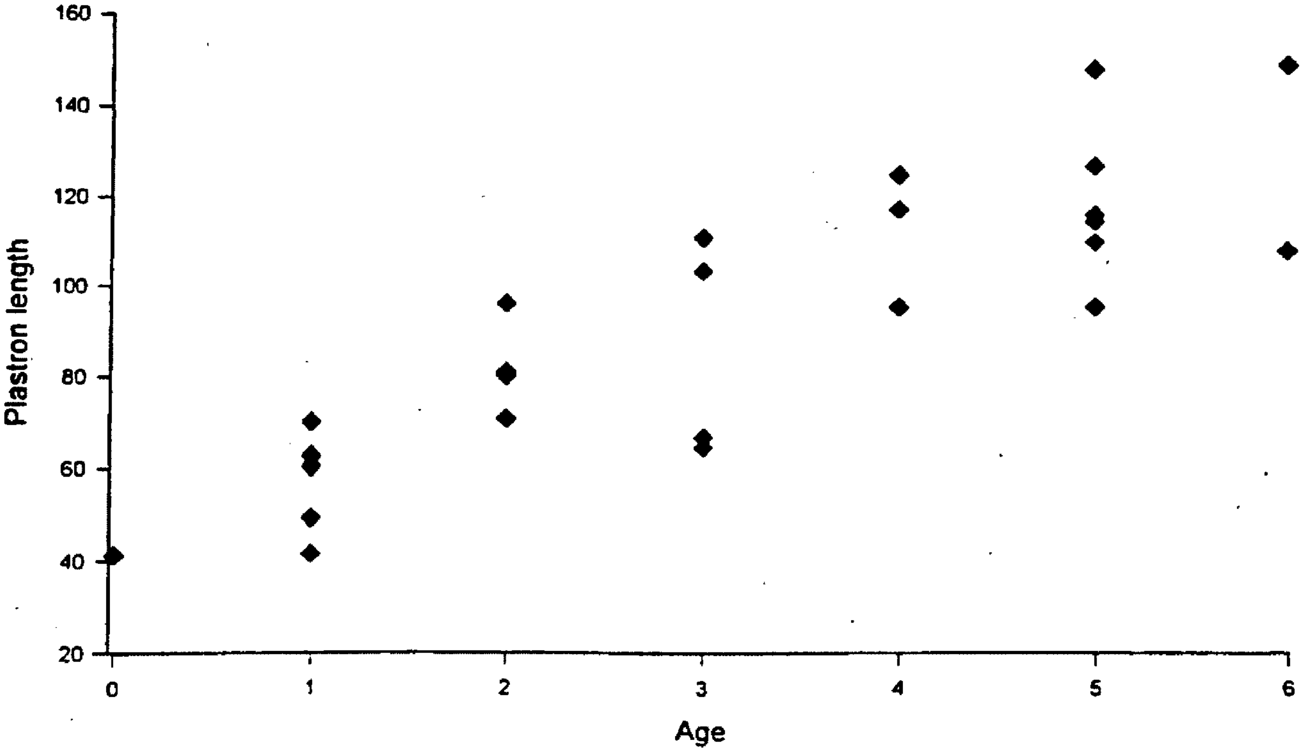


Figure 2.3b. Plastron length by age of juvenile turtles in the Mission Valley.

DISCUSSION

Model Reliability and Sources of Variability in Size

Like other methods used to determine painted turtle ages, my model operated on 2 assumptions: 1) each annulus visible in femur cross sections represented one year of growth; and 2) distinct, non-overlapping size ranges (PL or PW) made up each age class. We did not have any way to test the first assumption, although 37% of femur and shell annuli exactly matched indicates that growth annuli can occur on the shell or long bones for reasons other than the non-growing winter season (Zug 1991), or that growth annuli are not always visible. Some of this variability may be a result of our shell annuli counts. We counted the maximum number of ridges, and some of these may have been shallower ridges (e.g. results of environmental stress during the growing season) that appeared to add a year onto the count (Zug 1991). Most of the shell counts that did not match femur counts were "undercounts" of shell annuli (Figure 2.2), possibly due to loss of outer layers of the shell.

The second assumption was one made for most turtle aging methods, despite the many documented sources of variation in growth rates of freshwater turtles. Several studies suggested that turtle growth was environmentally influenced by nutrient content in the diet (Knight and Gibbons 1968, Lindeman 1996), degree of carnivory (Gibbons 1967, MacCulloch and Secoy 1983, Lindeman 1996), average annual temperature and length of the growing season (Frazer et al. 1991 and 1993), population density and availability of resources (Gibbons 1967, Wilbur 1975b, Dunham 1980, Hart 1982, MacCulloch and

Secoy 1983, Dunham and Gibbons 1990), and water and basking temperatures (MacCulloch and Secoy 1983). I found that turtles in ponds adjacent to the highway grew faster (Figure 3.7). Anthropogenic sources of pollution may increase turtle growth rates by increasing the nutrients in their diet (Knight and Gibbons 1968, Lindeman 1996). This may have been a source of increased growth rates in the highway ponds. However, Knight and Gibbons (1968) and Lindeman (1996) discovered this trend in sewage wastewater ponds, and the Mission Valley highway ponds are not subject to such high levels of increased nutrients. Another factor that increases growth rate in amphibians and reptiles is decreased population density, resulting in increased availability of resources (Gibbons 1967, Wilbur 1975b, Dunham 1980, Hart 1982, MacCulloch and Secoy 1983, Dunham and Gibbons 1990, Russell et al. 1996). Turtles in ponds near the highway may have been growing faster than those in ponds farther away in response to decreased density (see Chapter 3).

Older turtles showed the most variability in size, consistent with results from other painted turtle studies (Sexton 1959, Gibbons 1968, Wilbur 1975b, MacCulloch and Secoy 1983, Frazer et al. 1991). Another consistency with these studies was that older turtles tended to reach asymptotic growth or actually be smaller than turtles 2-3 years younger (Figure 2.3). Frazer et al. (1993) found that a general warming trend during the 1980s was correlated with faster growth rates of juvenile turtles in the late 1980s, as compared to juveniles in the same study area in the early 1980s. The same warming trend could explain the smaller sizes of older turtles in the Mission Valley. Alternatively, slower growth may be a life history strategy for increasing longevity, thereby increasing reproductive output (see Parma and Deriso 1990).

Because the model was based on size (plastron width), it underestimates the ages of older turtles. PWs of turtles >18 years old fit into the PW size range for 12-14 year olds (Figure 2.3a). This model (or any size-based model) cannot detect differences in ages between turtles with the same PW, or other measurement. Therefore, in using this model to predict ages, all turtles approximately 12+ years old should be regarded as one group.

Predictive Power of Plastron Width vs. Length

Other size-based aging models for painted turtles were based on PL (Gibbons 1968, Wilbur 1975b, Frazer et al. 1991) or medial annulus length (Sexton 1959). However, I found that PL was not significantly correlated with adult female age. Comparison of the length-to-width ratios of males and females indicated that females continue to grow in width more than length in later years (e.g. the ratio of length to width decreases) (Figure 2.4). This may be related to the positive correlation between clutch size and body size documented for this species (MacCulloch and Secoy 1983, Lindeman 1988, Gibbons and Greene 1990, St. Clair et al. 1994, Lindeman 1996), and further study could indicate whether clutch size is more highly correlated with PW than with PL. Adult female painted turtles in the Mission Valley tended to be rounder in carapace shape than adult males, which resembled a pear shape in comparison. Further investigation into the relationship between clutch size and PW, rather than PL, is necessary to understand why adult females tended to grow more in PW at older ages.

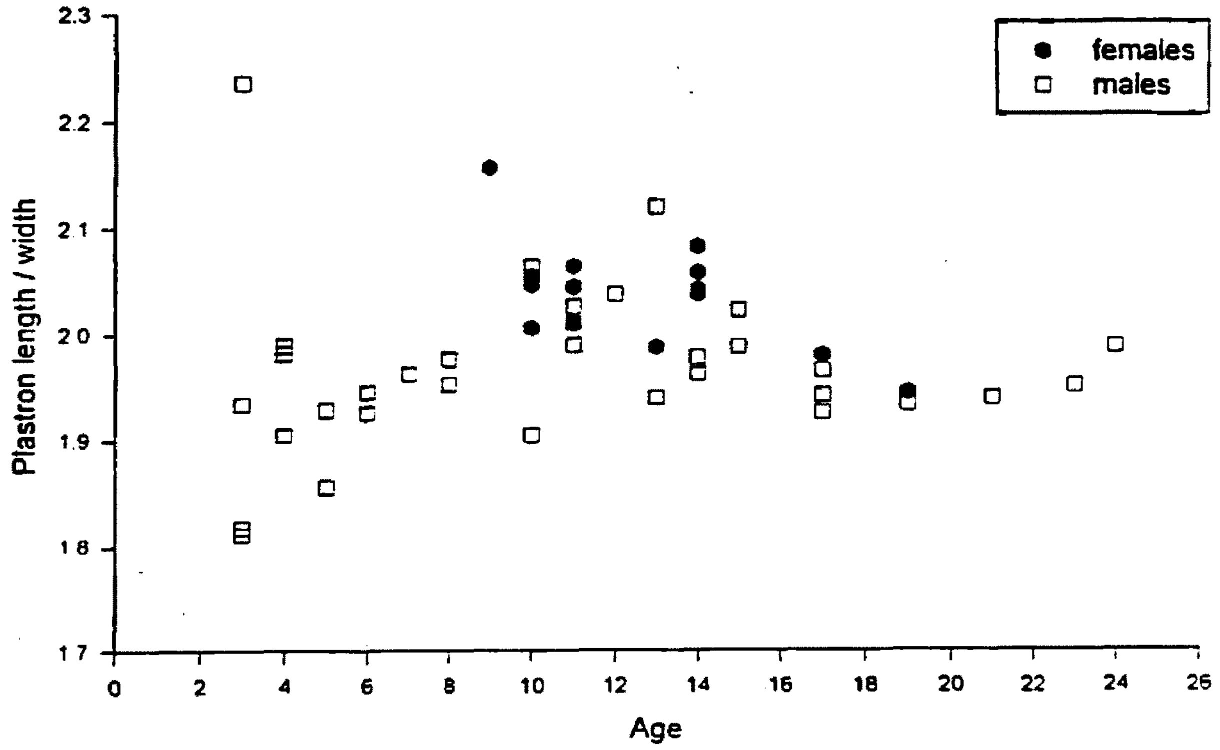


Figure 2.4. Comparison of plastron length-to-width ratios in adult males and females from the Mission Valley study area.

CONCLUSION

Because of the high degree of inter- and intrapopulational variation in painted turtle growth rates, this model may be more powerful as a predictor of stages rather than yearly age classes when comparing turtle populations and subpopulations. More information is needed on all sources of growth rate variation before this model can be applied to other western painted turtle populations. In addition, further investigation into the covariation of growth rate with latitude and elevation (Hart 1982, MacCulloch and Secoy 1983, Lindeman 1988, St. Clair et al. 1994, Lindeman 1996, Russell et al. 1996) is also necessary to the applicability of this model to other populations. This requires long-term interpopulational comparative studies as well as studies that distinguish environmental, temporal, and genetic sources of growth rate variation within the same region (Dunham and Gibbons 1990, Mitchell and Pague 1990).

I found 2 problems in previously-used methods for age determination and growth measurement of Emydid turtles. First, the number of annuli visible on the shell may not always represent years of growth. Second, plastron length is not always the best measure of growth, especially in adult females. Further investigation into lateral growth of the plastron and its potential relationship to clutch size is necessary to understand why plastron width might be a more powerful predictor of age.

CHAPTER III

EFFECTS OF ROADKILL MORTALITY

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 through inbreeding effects (Oxley et al. 1974, Diamond 1975, Bury 1982, Adams and Geis 1983, Reh and Seitz 1990) leading to 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. Rosen and Lowe (1994) found that snake populations adjacent to roads were declining due to roadkill mortality and had subsequently become population sinks. Snakes from populations farther away from the highway moved into the declining populations, probably responding to the decreased density and increased resources. I addressed the issue of roadkill mortality effects on the population of western painted turtles in the Mission Valley of western Montana.

Although roads may be only semi-permeable barriers to many species, 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," e.g. the width of the road or right of way (Oxley et al. 1974, Mader 1984). US Highway 93, a 2-lane highway, passes through a network of prairie pothole wetlands on the floor of the Mission Valley, and the number of road-killed painted turtles has raised public concern in recent years.

My objective was to 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. The study was a cooperative effort between the Montana Department of Transportation (MDOT), the Confederated Salish and Kootenai Tribes, the Montana Department of Fish, Wildlife and Parks, 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 described options for widening the highway to accommodate increasing levels of traffic (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 3 years (Frazer et al. 1991, Chapter 2). Females live up to

34 years and reach sexual maturity at age 7 (Wilbur 1975a, Frazer et al. 1991, Chapter 2). Bet-hedging theory predicts that long-lived organisms are most vulnerable to population decline when adult or juvenile mortality increases, as opposed to decreases in nest success or hatchling survival (Pritchard 1980, Crouse et al. 1987, Congdon et al. 1994, Cunnington and Brooks 1996). Several authors have found that increased adult and juvenile mortality thus had a greater impact on population stability (Pritchard 1980, Crouse et al. 1987, Congdon et al. 1994, Cunnington and Brooks 1996).

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 required a level of juvenile survival that was 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. Without rapid increases in 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. (1994) predicted the number of adults would decrease by 50% in less than 20 years with a 10% annual increase in mortality on adults over 15 years of age.

Other documented causes of turtle declines include increased human recreation and the resulting increased predation (crows, raccoons) and roadkill levels (Garber and Burger 1995). Dodd (1983) concluded that the most likely factors contributing to the Illinois mud turtle's (*Kinosternon flavescens spooneri*) decline were habitat alteration and fragmentation due to agricultural practices, as well as direct adult kills and nest destruction by farm machinery and ploughing.

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 may not be able to tolerate the current or increased levels of roadkill mortality and predation. My 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. 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 4.5 mi (7.2 km) section of Highway 93, the section that runs through the concentrated pothole area. The potholes sampled lie on either side of that section of the highway, out to 1.5 mi (2.4 km) to the east and to the west. In other words, pond sampling took place within a 13.5 mi^2 (17.3 km^2) area of the pothole region that is bisected by Highway 93 (Figure 3.1).

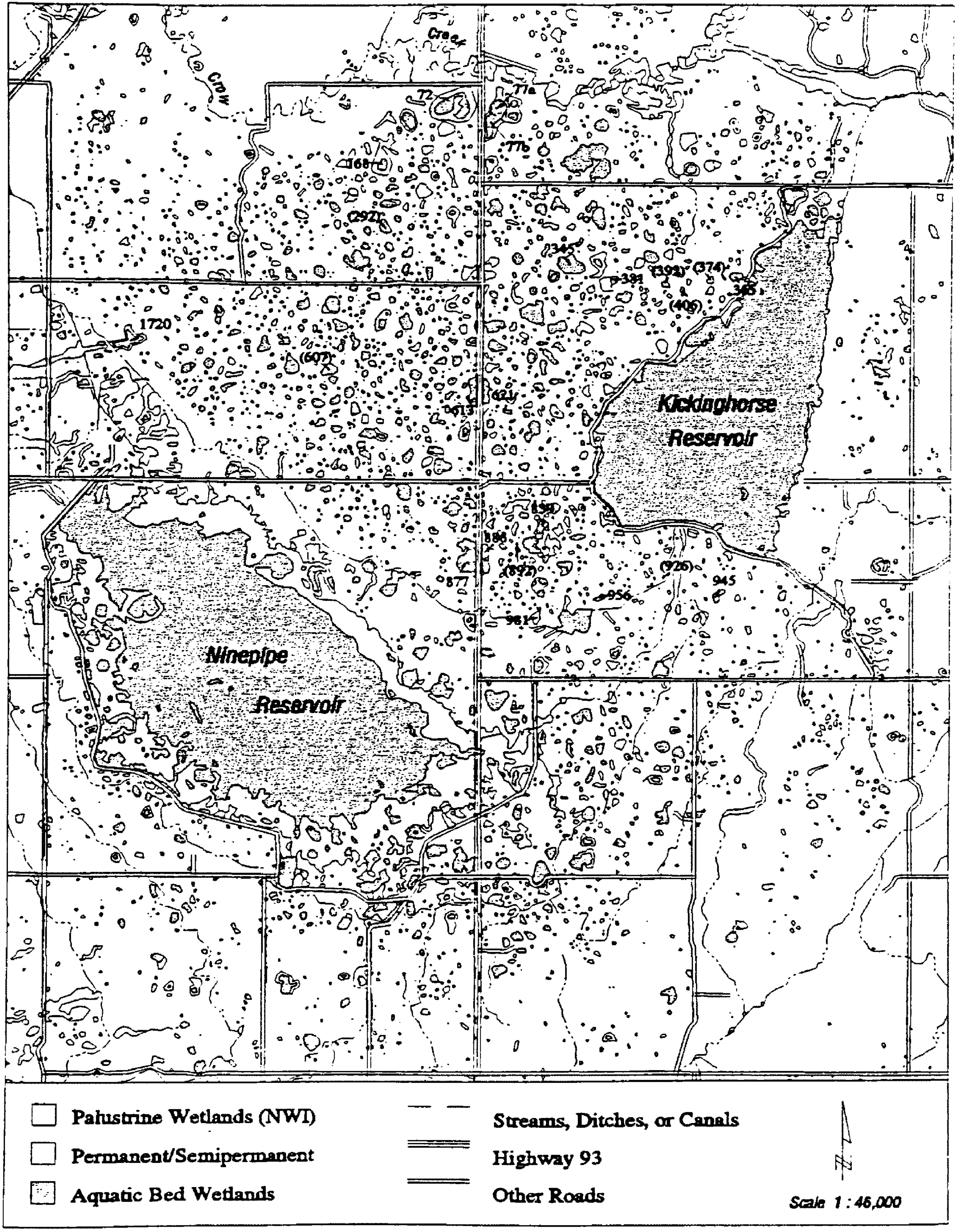


Figure 3.1. Map of the Mission Valley study area, with GIS-assigned numbers shown above sampled ponds (seasonal ponds shown in parentheses).

METHODS

Roadkill Collection

We collected turtles dead on the road (DOR) 3 mornings per week on the section of Highway 93 described above from 17 May to 24 August, 1995. We recorded the location of each turtle using evenly-spaced reflector posts along the roadside. We numbered each post (0 through 60) and estimated DOR turtle locations to the nearest reflector post or nearest midpoint between reflector posts (e.g. to the nearest 150 ft, or 45.6 m).

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 at Matson's Laboratory (Milltown, Mont.). We counted growth annuli and took 5 measurements on each turtle's shell (Figure 2.1): 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). 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 sufficiently intact 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 (see Chapter 2).

At the end of the field season, we walked along the west and east sides of the 4.5

mi (7.2 km) 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 were visible, and incomplete nests, which were abandoned nest attempts (empty holes excavated by female turtles). We could not see potentially successful, buried nests.

Turtle Trapping

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 1.5 mi (2.4 km) without coming closer than 0.5 mi (0.8 km) to any secondary roads. We sampled 16 permanent ponds and 7 ponds that dried up over the course of the field season. I only included data from the permanent ponds in the analyses. I did not sample any ponds with an edge less than 0.25 mi (0.4 km) from a secondary road in an effort to reduce variability due to roadkill on these roads.

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

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 4 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 adult/juvenile cut-off age.

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 (Appendix B). 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 120 mm in carapace length. We used a 1/8 in bit before 8 August and a 9/64 in 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 were active.

Examining Age and Size Distributions

All statistical analyses other than population estimations were computed using the SPSS software package. The age-predicting model for the Mission Valley turtle population was based on a regression equation that was used to estimate the ages of adults or juveniles from plastron width or length (see Chapter 2). The age distributions of live turtles were based on that model, using size at sexual maturity to separate adults and juveniles into the different models (160 mm PL for females, 93 mm PL for males, see Chapter 2). The age distribution of DOR turtles was based on the age determined by Matson's Laboratory (Milltown, Mont.) from femur cross sections.

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. Because turtle growth rates vary temporally as well as between ponds in the Mission Valley (see Chapter 2), I examined the age distributions using stage classes: Stage 2=4-6 years old; Stage 3=7-11 years old; Stage 4≥12 years old.

Using a chi square test, I compared the stage distributions of turtles in ponds <1/4 km away from the highway (Distance 1, n=448), between 1/4 and 1 km away from the highway (Distance 2, n=336), and >1 km away (Distance 3, n=233). I also compared the stage distribution of DOR turtles to these 3 distributions.

I tested whether average size varied significantly between turtles in ponds at these 3 distances. I used only turtles with 4 shell annuli to standardize the number of growing seasons as well as possible. Pooling all turtles at each distance would have maintained the sample bias, as would choosing turtles of a certain predicted age because the age-predicting model is based on size. I used turtles with 4 annuli because those with 5 and 3 annuli included large turtles that had apparently lost some of their older annuli, and these groups were therefore not normally distributed. I analyzed the differences in average plastron lengths (PLs) using a one-way ANOVA.

Population Estimation

Adult population densities were calculated for 8 ponds at different distances from the highway using the Lincoln-Petersen model. Only these 8 ponds had high enough sample sizes and recapture rates to estimate adult population size. In 5 of the 16 permanent ponds sampled, we captured less than 6 turtles all summer. In another 3 ponds, we recaptured only 1 or 0 adult turtles, although the total numbers of captures in these ponds were 40, 60, and 68.

Although the number of turtles found DOR indicated substantial movement over land, population closure was assumed for each pond because the data were insufficient to estimate survival rates or emigration/immigration rates over the course of the season. Only 2 DOR turtles were marked and from a known location. In addition, the recapture rates within each pond sampled were generally too low to estimate birth/death or emigration/immigration rates between sampling occasions.

Program CAPTURE (Otis et al. 1978) was initially used, but selected 5 different models for the 5 ponds tested. This may have been due to low recapture rates, since CAPTURE often selects incorrect models in such cases (Menkens and Anderson 1988). Menkens and Anderson (1988) and Dr. Colin Henderson (Department of Biological Sciences, University of Montana, pers. commun.) suggested pooling capture occasions and using the Lincoln-Petersen model as an alternative to CAPTURE. I pooled the capture occasions (e.g. the days traps were checked) into 2 categories: marking effort and recapture effort. All ponds in which we were unable to do a final "sweep" of turtles (e.g. with dip nets or seine nets) were pooled in the same way: turtles caught during the first 2/3 of the capture days were entered into the total number of turtles marked (n_1); turtles caught during the last 1/3 of the capture days were entered into the recapture values (n_2 and m_2). I estimated the population of 5 ponds this way (Ponds 72, 613, 621, 886, and 945).

We conducted recapture "sweeps" in 3 ponds (Ponds 877, 345, and 365) involving major capture efforts with dip nets or seine nets to increase the sample size. For these ponds, I used the results of those sweeps as the recapture values, rather than split the ponds after 2/3 of the trap days had occurred. In 2 of those 3 ponds (Ponds 345 and 365), we swept twice towards the end of the season to increase sample size and decrease confidence intervals. These two sweeps, as well as the trap days in between sweeps, were pooled into the recapture values for these 2 ponds. In the third pond (Pond 877), we only swept once, on the last day of the field season. All captures before the first (or only) sweeps were entered into the total number marked.

Because 77% of all captures (n=1,048, not including recaptured animals) occurred in basking traps, I tested whether basking traps were equally likely to catch adults and juveniles. As discussed in Chapter 1, I assumed that the dip nets and seine nets caught accurate proportions of adults and juveniles and compared these methods to the basking traps. I used data from 2 ponds with high sample sizes: one in which we caught 73 turtles in dip nets and 71 in basking traps (Pond 365); and another in which we caught 63 turtles in seine nets and 162 in basking traps.

Juvenile and adult capture rates differed significantly in the basking traps (Pond 365, Pearson value=10.38, P<0.01; Pond 345, Pearson value=20.42, P<0.010) (MacCulloch and Secoy 1983), so I separated adults and juveniles in estimating population sizes to avoid violating the assumption of equal catchability. Because juveniles were less likely to use the basking traps, only 3 ponds had large enough juvenile sample sizes to estimate juvenile population sizes, the same 3 ponds with high sample sizes and recapture rates due to sweeping efforts (Ponds 877, 345, and 365). In these 3 ponds, I estimated juvenile and adult population sizes separately, using the Lincoln-Petersen model for both. I added the 2 estimates together to estimate total population size and turtle density. I only estimated adult population sizes in the other 8 ponds mentioned above.

RESULTS

Locations of Roadkills and Nest Sites in the Right-of-Way

We counted 205 DOR turtles on the study section of Highway 93. This is the minimum number of mortalities that occurred during the field season; the number does not include turtles removed from the road by scavengers, those sent off the road by the impact of the vehicle, or those that survived the impact initially and were able to walk away from the road. Turtles can survive serious injury, as indicated by the 42 captured turtles with chipped shells (4%), 26 with scars from cracked or punctured shells (2%), and 12 turtles missing one or two limbs (1%, n=1,048 captures). Roadkill locations spanned the 4.5 mi (7.2 km) section continuously, with a high concentration at the north end of the study area (Figure 3.2). The longest distance between mortality sites for 1995 was about 0.25 mi (0.4 km).

We found 5 detectable nest sites on the east side of the highway and 11 on the west side (Figure 3.2). These sites were either on the embankment next to the road shoulder or within approximately 3 m of the bottom of the embankment.

Seasonality of Roadkills

The major pulse of DOR turtles occurred from late May to mid July (Figure 3.3). 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

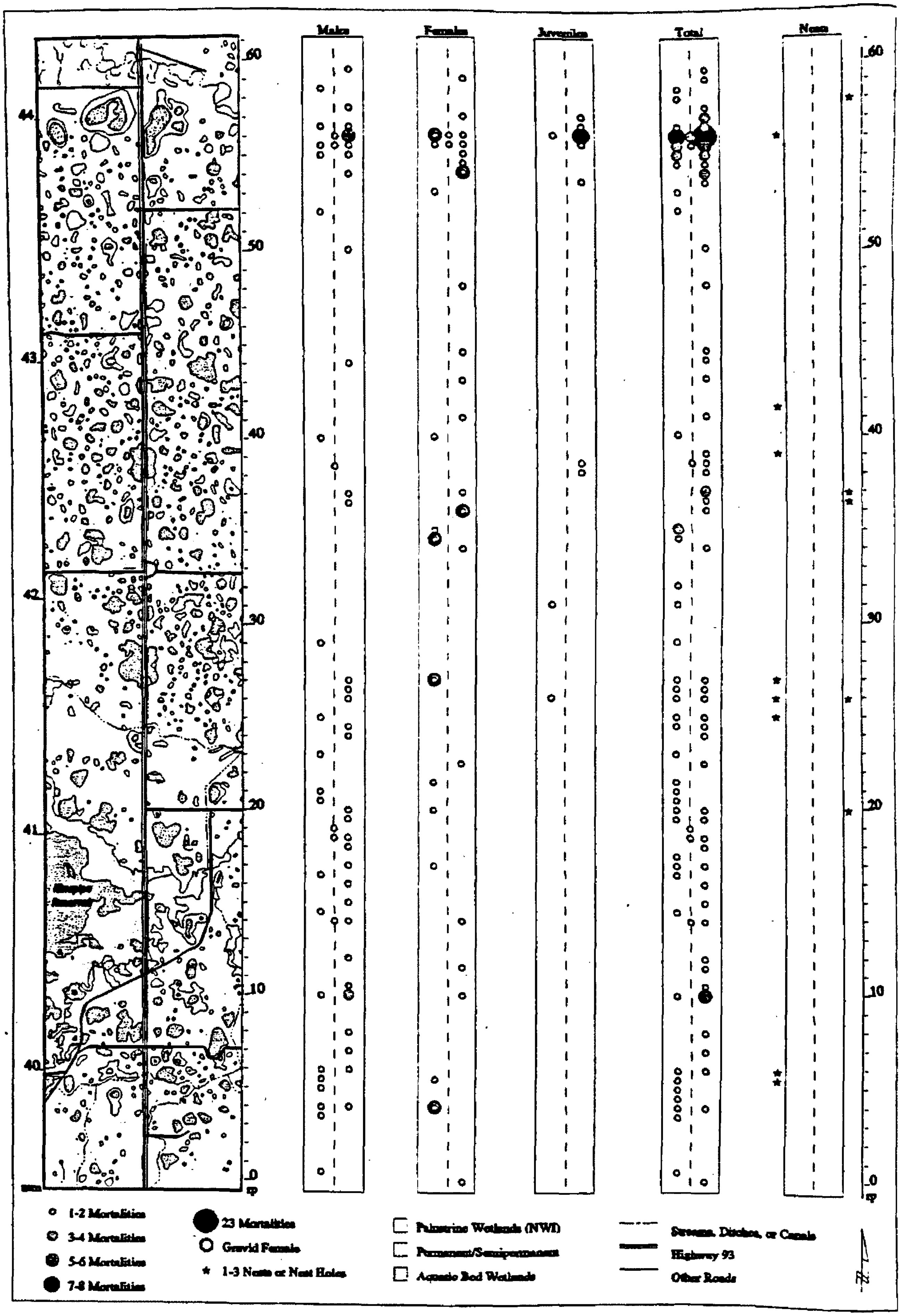


Figure 3.2. Map of DOR turtle and nest site locations in the study section of Highway 93

early July. Males and juveniles killed on the highway were more evenly distributed across the field season.

Sex Ratios

DOR turtles consisted of 43% adult males (n=88), 26% adult females (n=54), and 31% of unknown sex (n=63), including juveniles (Figure 3.4a). Seventy-two percent of the juveniles (18 out of 25 total juveniles) were from the area of highly concentrated roadkills (Figure 3.4b). We were unable to conclusively 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 1.2). Therefore, we do not know if proportionally more males or females were killed on the highway. However, when the sex ratios of all ponds were pooled together, the overall sex ratio was 1.9:1.

Age and Size Distributions

The age distributions in ponds at Distance 1 were significantly different from each other (Pearson value=25.8 , P<0.01) as were the age distributions in ponds at Distance 3 (Pearson value=18.4, P=0.01). However, the difference between distributions of ponds at Distance 2 was only marginally significant (Pearson value=12.01, P=0.06). Because these ponds could not be pooled together for goodness of fit tests between Distances, I qualitatively examined percentages of turtles belonging to each stage class at each Distance and DOR (Figures 3.5a-d).

The DOR turtle ages were evenly distributed from age 0 to 26, as compared to the

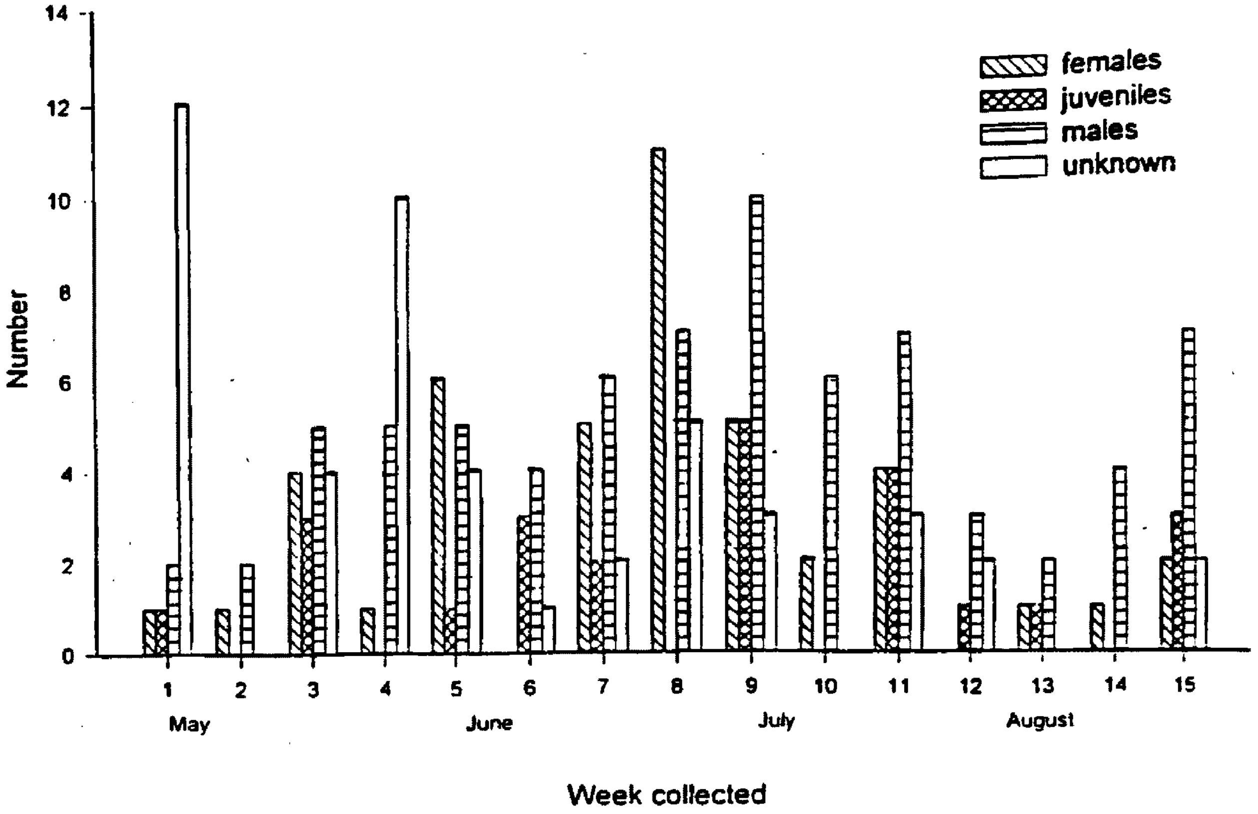


Figure 3.3. Seasonality of roadkills in the Mission Valley study area, by week of collection (from 17 May to 24 August 1995).

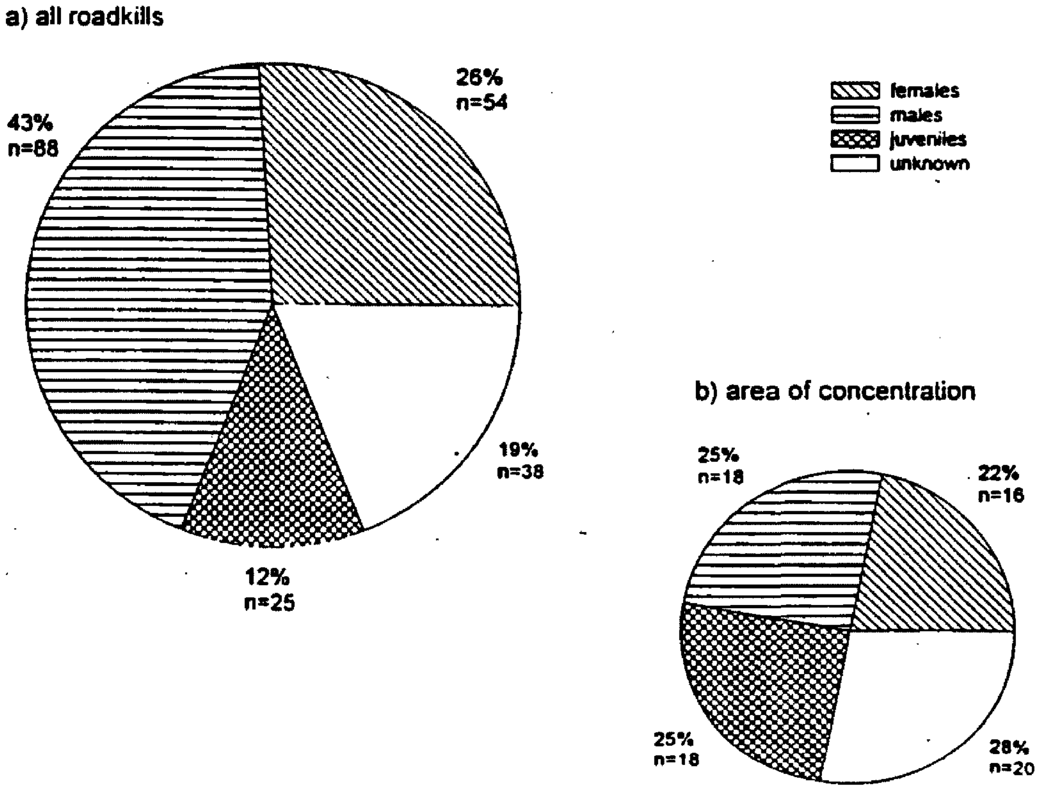
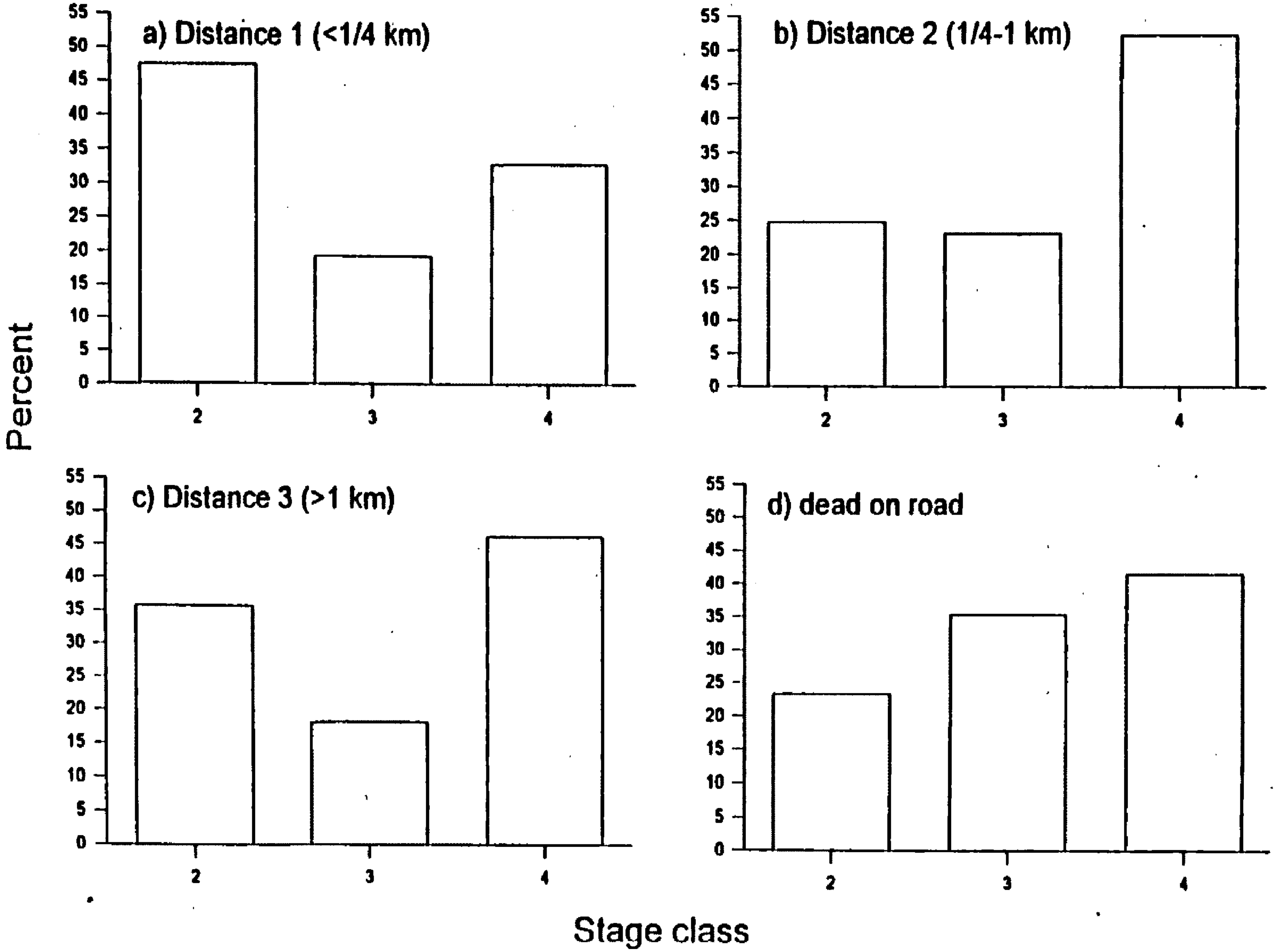


Figure 3.4a-b. Sex ratios of all DOR turtles found on the study section of US Highway 93 and in the area of concentration.



Figures 3.5a-d. 1995 capture records expressed as percents of turtles in each stage class by distance-from-highway category or DOR. Stages represent groups of age classes: Stage 2=4-6 years old; Stage 3=7-11 years old, and Stage 4≥12 years old.

distributions of live turtles. Distance 1 contained the highest percentages of juveniles and young adults (Stage 2, 48%), while Distance 2 consisted of the highest percentages of older adults (Stage 4, 52%). Both Distances 2 and 3 contained more adults and fewer juveniles than ponds at Distance 1 (Figures 3.5a-d). A consistent feature of the live turtle age distributions across all 3 distances is a lack of individuals in age classes 7 to 10 and a steep decline starting at age 5 (Figure 3.6).

Mean PLs of turtles with 4 annuli were significantly different between Distances 1, 2, and 3 (F ratio=28.6, $P<0.01$). These turtles were largest in ponds adjacent to the highway, and size decreased with increased distance from the highway (Figure 3.7).

Turtle Movements

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 0135 (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). 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.

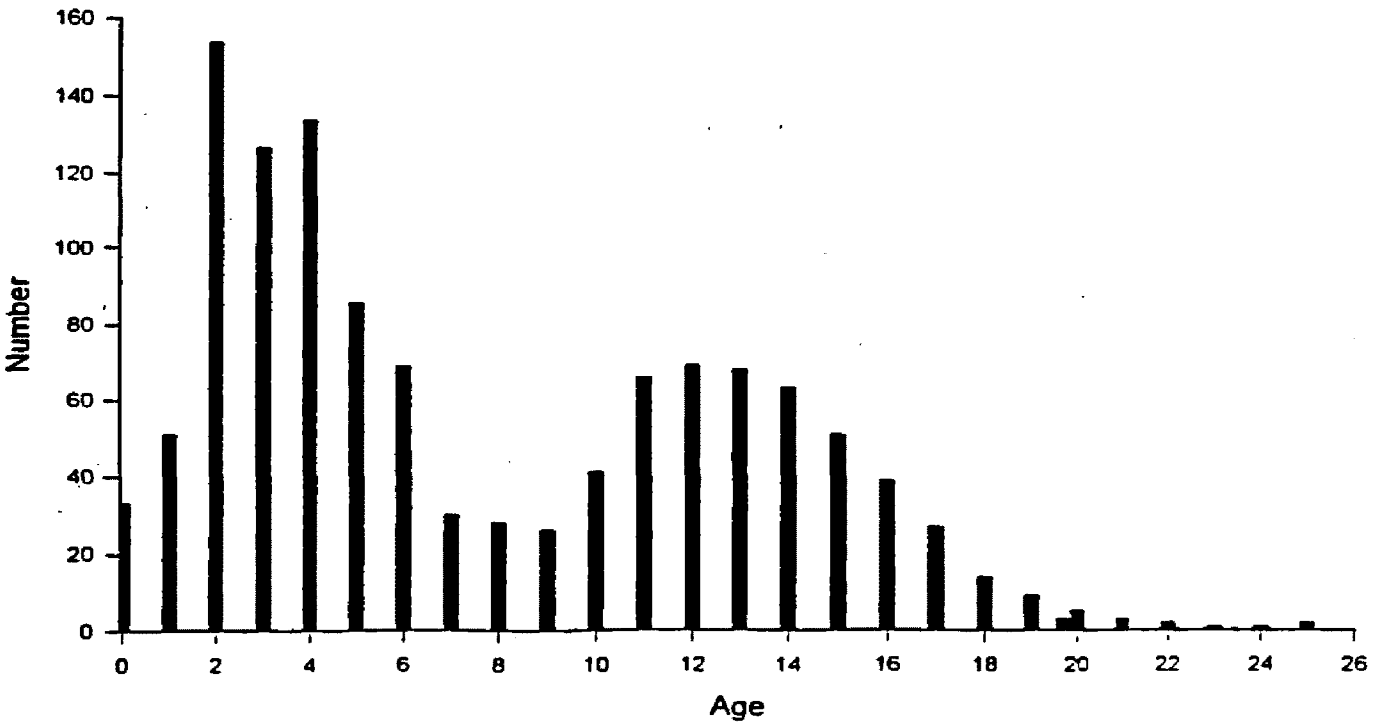


Figure 3.6. Age distribution of all live turtles marked, May-August 1995.

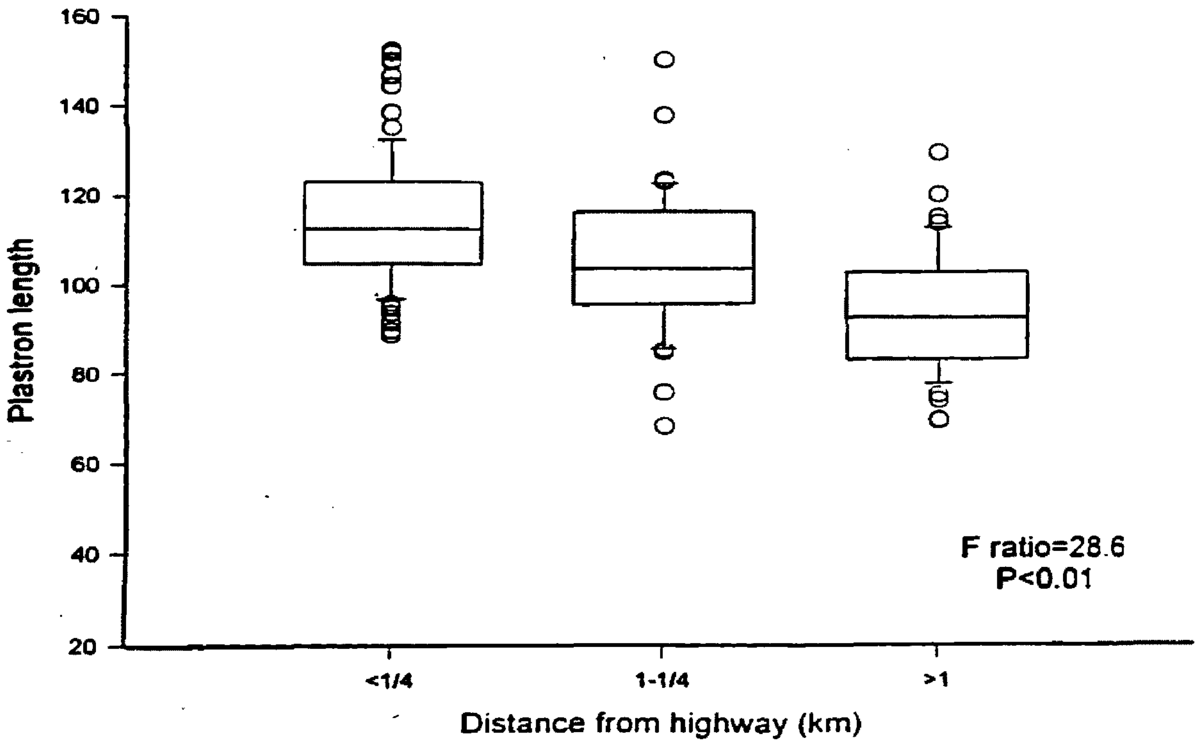


Figure 3.7. Mean plastron lengths of turtles (with 4 shell annuli) by distance from the Highway.

The distance moved mostly ranged from <0.1 to 1.1 km, with one turtle that moved a distance of 3 km. We detected 3, 1, and 3 movements among males, females, and juveniles, respectively (Table 3.1). One 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 may have been marked, but the roadkills were usually too damaged to be able to detect the presence of markings.

Population Densities

Densities of adult turtles were positively correlated with pond distance from the highway (Table 3.2). Approximately 57% of the variance in adult densities among these 8 ponds was explained by the ponds' distance from the highway (R^2=0.57, P=0.03) (Figure 3.8). Total turtle density (adults and juveniles) also declined as distance from the highway decreased, as estimated from the 3 ponds with the highest sample sizes and recapture rates (Table 3.3). Pond area (ha) was also correlated with adult density at a marginally significant level (Pearson correlation=-0.59, P=0.06). Regression analysis showed that adult density was not a function of pond area, at the 0.05 significance level (R^2=0.35, P=0.13). However, pond area and distance from highway happened to be correlated for these 8 ponds (Pearson correlation=0.63, P=0.05), so I was unable to separate the effects of these 2 variables.

Table 3.1. Recaptured turtles that moved between ponds in the Mission Valley.

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 across highway.

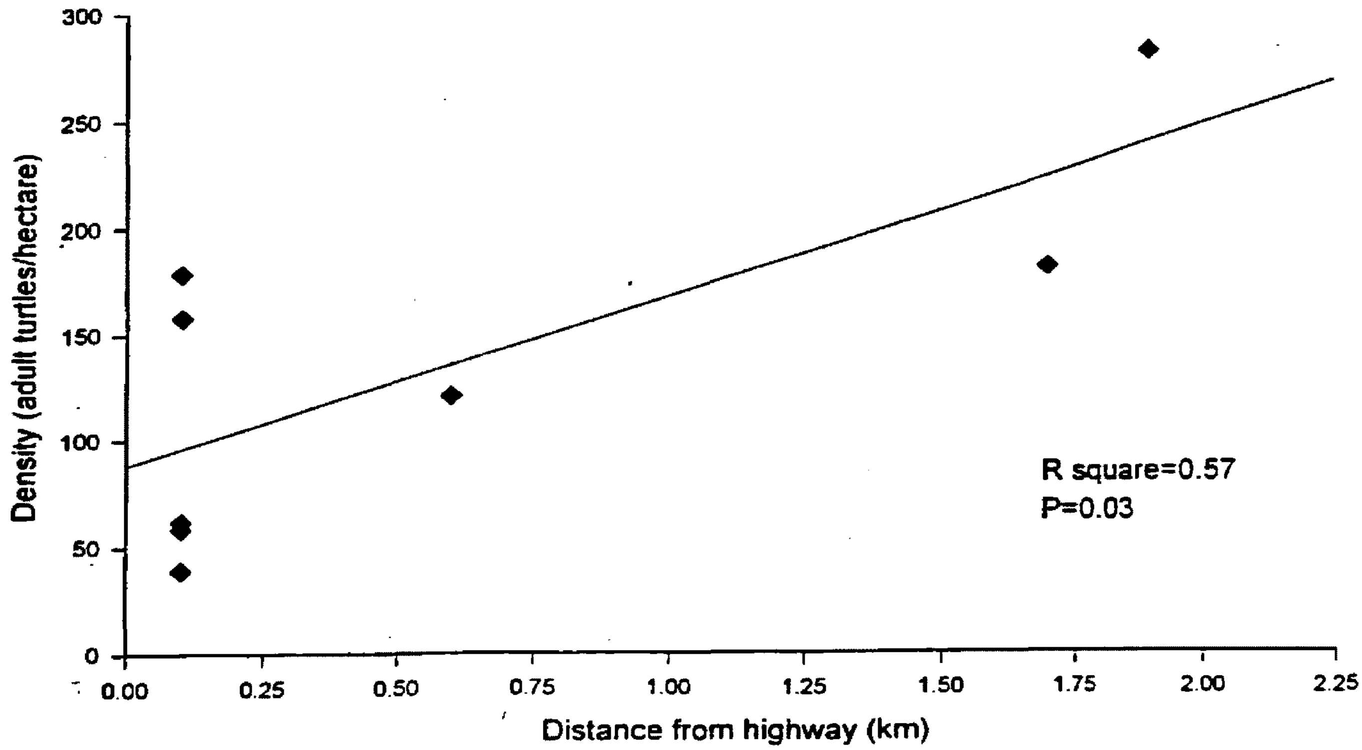


Figure 3.8. Relationship between adult turtle density (in 8 ponds) and pond's distance from US Highway 93.

Table 3.2. Estimated population densities of adult turtles in the Mission Valley study area.

Pond no.	Pond size (ha)	Adult turtle density (turtles/ha ±95% CI)	Pond's distance to highway (km)
877	3.40	39±16	<0.1
886	1.30	59±18	<0.1
613	1.52	62±38	<0.1
72	2.84	158±90	<0.1
621	1.04	178±134	<0.1
345	2.24	121±29	0.6
945	0.57	182±128	1.7
365	0.54	283±85	1.9

Table 3.3. Adult and juvenile population estimates for 3 ponds sampled in the Mission Valley.

			Population estimates (±95% confidence interval)				
Pond no.	Pond size (ha)	Sample period	Adults	Juveniles	Combined	Combined density (turtles/ha)	Pond's dis to high (km
877	3.40	6/11-8/22	134±56	59±46	193±82	57±24	<0.1
345	2.24	6/14-8/12	272±64	97±71	369±47	165±21	0.6
365	0.54	6/19-8/12	153±46	156±80	309±87	572±161	1.9

DISCUSSION

Roadkill Locations and Characteristics

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, but used 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 fact that 72% of the DOR juveniles were found in the area of highest concentration of roadkills, mostly on the same side of the highway as a pond immediately adjacent to the road shoulder, indicated that juveniles as well as adult painted turtles disperse from their ponds (Figure 3.4). However, factors that signal juvenile dispersal are not well understood. The ponds we sampled that dried up during the course of the field season generally consisted of more juveniles than adults (67% juveniles in seasonal ponds versus 27% juveniles in permanent ponds). The adults may have dispersed first as the ponds began to lose water. The maximum number of DOR juveniles collected on any day in the high concentration area was 4. The maximum was collected on 2 occasions, on 9 July and 23 July. In contrast, the maximum number of adults collected on any day (also 4) in this area was collected much earlier in the season, on 15 June.

The pond adjacent to the high DOR concentration did not dry up by late August.

However, during wetter years, this pond is connected to another adjacent pond (ponds 77a and 77b). During my study, the 2 ponds were separated by a band of dry mud. The pond areas were each approximately 0.3 ha, although the area of the 2 ponds connected usually equals 2.5 ha. Both ponds were devoid of vegetation. The movements from these ponds may be an example of turtles leaving temporary wetlands or wetlands that were otherwise unable to support substantial turtle populations.

The sex ratio, DOR locations, and age distributions we found could be better explained in comparison to historical 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. For example, the section of Highway between Ponds 886 and 877 may have once been an area of high concentration of roadkills, as indicated by the fact that both marked DOR turtles came from Pond 886, as did turtle "BL," the turtle that crossed the road successfully, from Pond 886 to 877. The possibility of temporal variation in areas of concentrated roadkills may complicate management strategies (e.g. choosing culvert locations).

Overland Movements

Gibbons et al. (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 (Sexton 1959, Gibbons et al. 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. Water-filled ponds were farther apart during the summer of 1995 than in most years in the Mission Valley.

From 26 years of mark-recapture data collected at the Savannah River Site (South Carolina), Burke et al. (1995) found that 3.9% (n=65) of the 1,660 slider turtles (*Trachemys scripta*) originally marked in one wetland site were recaptured at other sites. The 7 painted turtles that moved from their original capture sites in the Mission Valley make up 0.7% of the 1,048 turtles marked during the summer of 1995. This may be a result of dry conditions in 1995, assuming slider and painted turtle metapopulation dynamics are comparable, and assuming dry years cause turtles to be more sedentary rather than more mobile, in search of non-existent temporary ponds. The lower number of dispersers in the Mission Valley also may reflect the much shorter duration of study.

The 3 km distance recorded (Table 3.1) would require the turtle “IN” to have crossed Highway 93. Although adult painted turtles have been known to travel as far as 2.1 km (McAuliffe 1978), this turtle was a juvenile and would have had to travel a longer distance (3 km) to reach its site of recapture. 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 et al. 1990). She may have been helped across the road by people driving by; 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 turtles that moved agrees with Gibbons et al.’s (1990) conclusion that females are more sedentary. However, as discussed earlier, we do not know if the DOR sex ratio also indicates this.

Gibbons et al. (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.

Effects on Age Distributions

Proportionally more juveniles (4-6 years old) and proportionally fewer adults (≥12 years old) were found at Distance 1 (n=7 ponds) than found in both Distances 2 and 3 (n=5 ponds and n=4 ponds, respectively), implying that roadkill mortality may be killing proportionally more adults. Frazer et al. (1991) found that juvenile growth rate and turtle density increased at the same time survival rates decreased. Roadkill mortality may be causing this pattern in the Mission Valley. Roadkill mortality may also be significant enough to cause a decrease in turtle density, thereby decreasing juvenile-adult competition for resources (including basking sites), increasing juvenile survival rates, and potentially increasing juvenile catchability in basking traps (Lovich 1988). However, more information on juvenile dispersal and hatchling movements is necessary to understand this age distribution.

The low numbers of turtles in age classes 7-10 does not correspond with any single weather trend, such as fluctuation in average annual temperature or precipitation. However, various combinations of temperature and precipitation variability may have contributed to decreased recruitment rates 7-10 years ago as well as changes in growth rates and resulting inaccurate age predictions. For example, the drought of 1988 (32.05 cm of precipitation) may have caused a decrease in nest success. The high average temperatures for 1987 and 1988 may have resulted in increased turtle growth rates which caused the age-predicting model to overestimate ages of turtles hatched during those years. Effects of annual environmental fluctuations may span more than one predicted age class because the age-predicting model assumes discrete size ranges for each age class.

In addition, the skunk (*Mephitis mephitis*) population in the pothole region was controlled from 1988 to 1993 (reduced by approximately 80%), possibly resulting in increased nest success and a pulse of turtles hatched after 1988 (younger than 7 years old). Skunks have been documented preying on turtle nests (Gibbons 1968, Tinkle et al. 1981, Snow 1982, Christens and Bider 1987). The bimodal distribution of ages in the Mission Valley population (Figure 3.6) was augmented by the fact that a second peak occurred at ages 12-14. This is at least partially explained by older turtles tending to be within the size ranges of 12-14 year olds (Figure 2.3a). Further, femur annuli counts were generally less reliable for older turtles due to resorption of early annuli (G. Matson, Matson's Laboratory Director, pers. commun.).

Some degree of instability in age distributions of long-lived, bet-hedging species populations may be expected. Bet-hedging theory suggests that longevity and high adult survival rates of iteroparous species account for unstable recruitment rates (e.g. recruitment rates that are vulnerable to environmental fluctuations) (Congdon and Gibbons 1990, Cunnington and Brooks 1996). Further monitoring of this population will indicate whether it might eventually reach a stable age distribution or always exhibit some degree of bimodality, evidence of environmental variability.

Effects on Population Densities

The significant difference in mean PL among turtles with 4 annuli may be an indication of lower turtle densities in ponds next to the highway. Increased growth rates in response to decreased densities and increased availability of resources have been documented for reptiles and amphibians (Gibbons 67, Wilbur 1975b, Dunham 1980, Hart 1982, MacCulloch and Secoy 1983, Dunham and Gibbons 1990, Russell et al. 1996).

The low percentage of marked turtles that moved makes the assumption of population closure in each pond more realistic, at least for the summer of 1995, although the Mission Valley turtles clearly exhibit a metapopulation dynamic. Population density estimates support the hypothesis that proximity to the highway results in population decrease (Tables 3.2 and 3.3, Figure 3.8). Only 57 turtles per hectare of water area were estimated in a pond <0.1km from the highway, whereas 165 and 572 turtles per hectare were estimated in ponds 0.6 and 1.9km from the highway. The estimates made by program CAPTURE, using a different model for each pond, show the same trend of decreasing density closer to the highway (Figure 3.9).

Pond variables other than distance from the highway (e.g. pond size, vegetation type, water temperature, pH levels, substrate, dissolved oxygen content) also affect turtle density. In the pond adjacent to the area of highest roadkill mortality (Pond 77b), only 1 turtle was caught, using a seine net. We caught only 5 turtles in an adjacent (Pond 77a), also near the area of high DOR concentration. However, capture rates were equally low in 3 ponds farther away from the highway. In these ponds, all over 0.25 km from the highway, we caught only 1 or 2 turtles (Table 3.4). Although pond size (area) was not as highly correlated with adult density as distance from the highway, it appears to be an important variable. Further investigation into pond size and other variables is necessary to interpret population densities and understand turtle habitat use.

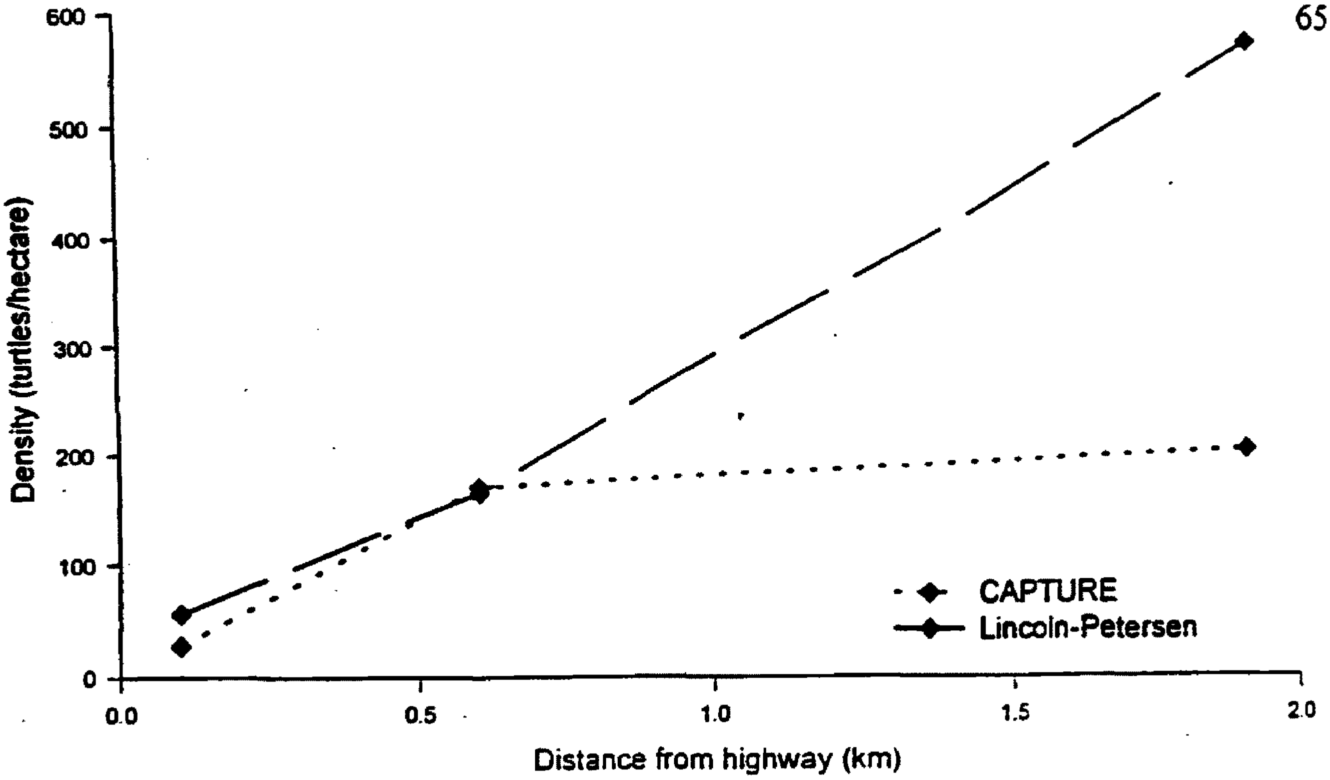


Figure 3.9. Comparison of population estimates from CAPTURE and Lincoln-Petersen models.

Table 3.4. Total number of turtles captured in ponds with low sample sizes.

Pond no.	Total no. captured	Distance to highway (km)
77a	5	<0.1
77b	1	<0.1
956	1	0.4
981	2	0.4
381	1	1.0

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 sustain 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). The most effective method for increasing permeability of roads is to elevate (bridge), thereby removing the barrier (De Santo and Smith 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 and Smith 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. 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 these are burrowing animals.

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 Jackson and Tyning 1989). 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.

Funneling 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 funneling 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 animals' stress caused by traffic (De Santo 1993).

CONCLUSION

In the Mission Valley, all ages of turtles and both sexes moved overland, and connectivity between ponds and between ponds and nest sites must be maintained. Informed management decisions for turtles in the Mission Valley will depend on an understanding of their movements and habitat use patterns. The distance turtles are willing to travel will indicate whether turtles are traveling to ponds next to the highway, which are possible population sinks (Rosen and Lowe 1994). Understanding metapopulation dynamics of freshwater turtles requires long term study and large sample sizes (Burke at al. 1995). Therefore, continued monitoring is essential to conservation of this turtle population. Future monitoring also could indicate whether secondary roads and/or agricultural practices are contributing to habitat fragmentation and direct mortality (see Mader 1984, Dodd 1983, Doroff and Keith 1990).

The population density estimates presented here indicate that Highway 93 is a significant and constant source of mortality for painted turtles in the Mission Valley. Although survival rates are not known for this population and cannot be compared to those of other painted turtle populations, we know that long-lived, slow-growing organisms are extremely vulnerable to increases in mortality, especially of adults (Pritchard 1980, Dodd 1983, Crouse et al. 1987, Doroff and Keith 1990, Brooks et al. 1991, Congdon et al. 1993, Congdon et al. 1994, Garber and Burger 1995, Cunnington and Brooks 1996). Therefore, roadkill mortality in the Mission Valley is likely to be causing this population, or certain subpopulations, to decline.

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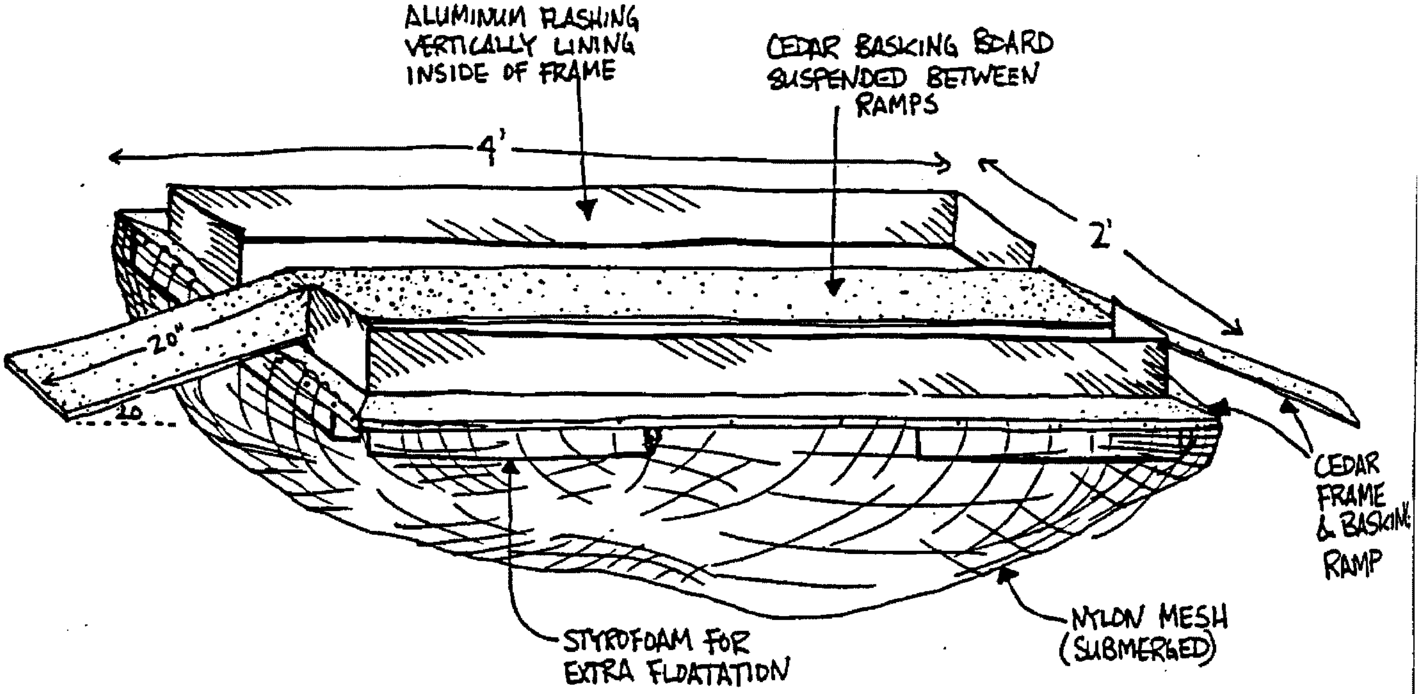
APPENDIX A
BASKING TRAP DESIGN AND EFFICIENCY

Basking trap efficiency averaged 2.1 turtles per trap per trapping occasion. The duration of trapping occasions was 2 days (e.g. checking each trap every other day). The dimensions and materials used to build basking traps are shown below.



APPENDIX B
ILLUSTRATION OF MARKING SYSTEM

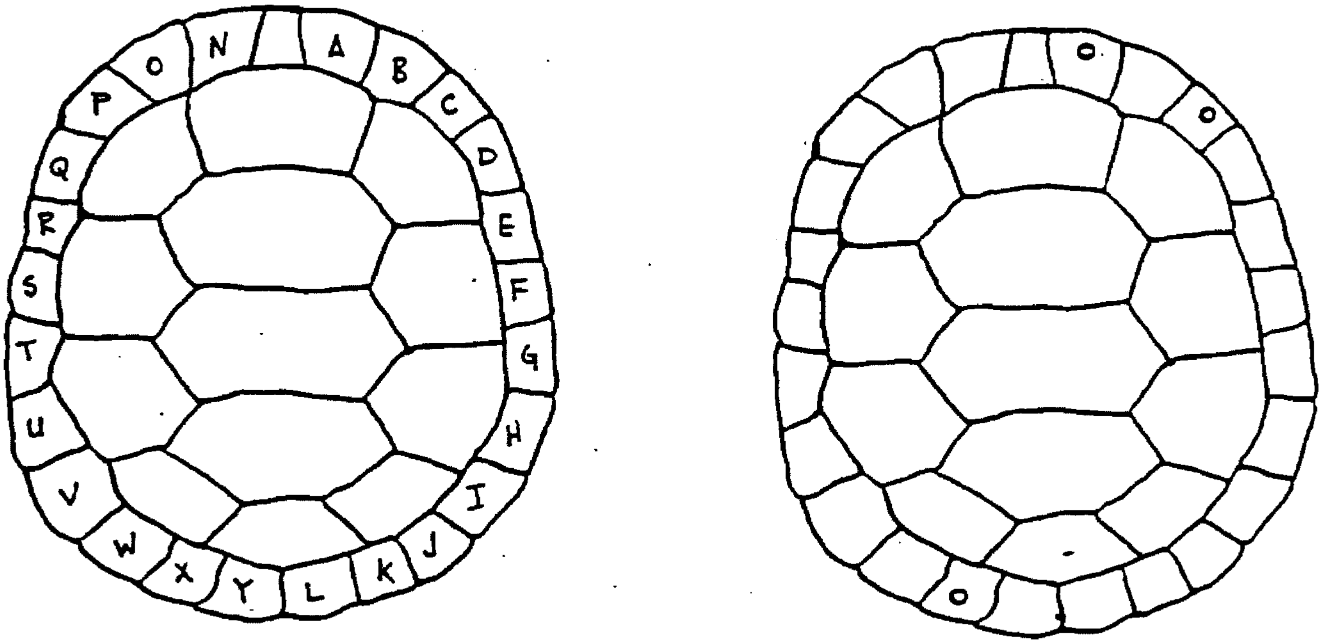


Illustration of marking system with example (turtle code "ACX").

APPENDIX C
RECORD OF TURTLE CODES AND CAPTURE LOCATIONS

(all turtles marked 20 May to 23 August, 1995)

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
A	1366	f	165.6	154.5	x
AB	888	f	118.5	112.8	58.7
ABC	621	m	176.8	159.9	83.5
ABCH	345	m	124.2	113.6	60.7
ABCI	345	j	92.2	85.4	49.0
ABCJ	345	j	65.0	59.2	35.5
ABCK	345	j	57.1	52.6	28.6
ABCL	345	j	92.6	85.0	47.6
ABCN	345	j	84.9	78.8	42.0
ABCO	345	j	90.8	88.1	45.6
ABCP	345	m	177.6	163.3	83.3
ABCPW[1]	365	m	116.7	107.4	56.8
ABCU	345	m	176.4	169.6	86.1
ABCV	345	m	158.1	147.7	75.5
ABCW	345	m	168.9	161.1	83.2
ABCX	345	m	170.5	155.8	85.8
ABCY	345	m	155.5	144.1	73.5
ABH	621	f	186.1	186.1	86.0
ABHI	345	m	143.4	133.8	67.7
ABHJ	345	m	121.6	116.0	58.8
ABHK	345	m	120.5	116.1	62.1
ABHL	345	m	124.4	112.8	59.8
ABHN	345	m	114.8	116.1	57.4
ABHO	345	j	88.9	85.1	49.9
ABHP	345	j	90.4	81.9	46.6
ABHU	345	j	84.7	71.8	44.8
ABHV	345	j	93.9	85.3	48.7
ABHW	345	j	66.2	61.5	35.3
ABHX	345	j	96.2	86.6	50.0
ABHY	345	j	90.3	82.3	47.2
ABI	621	f	121.8	112.5	61.2
ABIJ	613	m	107.2	100.9	52.9
ABIK	613	m	182.3	170.0	86.1
ABIL	613	m	153.7	141.4	72.6
ABIM	613	m	182.7	173.6	83.1
ABIN	1720	m	109.9	102.2	52.9
ABIO	1720	m	166.6	153.7	76.5
ABIP	877	m	158.0	146.5	74.8

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
ABIU	877	m	146.2	137.3	71.5
ABIV	877	m	172.6	163.1	80.2
ABIW	839	f	173.6	162.2	78.4
ABIX	839	f	167.1	158.1	81.6
ABIY	839	f	176.3	171.9	85.9
ABJ	613	m	119.8	110.0	60.2
ABJK	345	j	95.7	87.3	45.5
ABJL	365	m	96.6	92.9	47.0
ABJM	72	m	179.4	165.0	84.0
ABJN	72	m	144.7	133.0	69.2
ABJO	72	f	113.7	110.7	61.6
ABJP	72	f	125.4	119.9	62.5
ABJU	72	f	110.9	107.9	56.8
ABJV	72	j	97.5	91.8	50.2
ABJW	292	m	110.2	102.0	54.2
ABJX	292	j	85.0	79.7	43.1
ABJY	621	f	119.9	113.6	59.7
ABK	613	f	122.5	112.2	61.7
ABKL	839	m	180.6	168.6	81.2
ABKN	926	m	188.3	177.0	85.4
ABKO	365	m	96.5	91.7	49.3
ABKP	365	f	172.9	167.1	85.4
ABKU	345	f	194.7	184.9	92.7
ABKV	345	m	181.8	165.4	83.9
ABKW	345	m	189.7	175.2	85.4
ABKX	345	m	177.2	164.3	82.7
ABKY	345	m	146.8	137.7	69.9
ABL	613	m	138.5	125.1	65.8
ABLN	72	f	124.5	119.6	59.9
ABLO	72	f	110.1	102.8	56.0
ABLP	72	m	127.9	123.5	63.8
ABLU	72	f	132.2	129.7	66.4
ABLV	72	f	122.4	116.0	59.9
ABLW	72	j	89.3	82.7	46.8
ABLX	72	f	124.6	115.4	63.8
ABLY	72	j	91.3	85.9	48.9
ABN	1720	f	176.0	169.9	87.6
ABNO	621	j	60.7	55.3	32.5
ABNP	72	f	119.1	110.3	57.9
ABNU	72	j	91.8	83.4	47.4
ABNV	72	j	95.7	89.0	49.1
ABNW	72	m	102.9	94.1	51.6
ABNX	168	m	132.6	127.4	67.6
ABNY	168	f	142.5	136.1	70.6
ABO	1720	f	167.1	156.3	78.1
ABOP	292	j	85.2	80.5	42.7
ABOU	1720	m	175.8	166.0	85.6
ABOV	1720	f	125.4	120.5	60.2
ABOW	607	j	65.6	61.3	35.5
ABOX	345	m	183.6	168.0	85.5

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
ABOY	839	m	188.0	171.8	87.7
ABP	1720	m	169.5	156.7	78.0
ABPU	345	m	122.9	114.1	60.6
ABPV	345	m	116.0	112.0	60.0
ABPW	365	m	140.5	132.7	69.1
ABPX	365	f	118.9	113.7	60.6
ABPY	839	m	178.8	162.3	85.0
ABU	607	j	68.9	62.2	35.7
ABUW	839	m	120.6	111.6	57.7
ABUX	839	m	173.6	164.0	81.2
ABUY	888	j	63.2	58.6	33.7
ABV	607	j	68.5	64.3	35.8
ABVW	839	f	175.1	167.1	85.1
ABVX	839	m	157.2	145.5	74.8
ABVY	839	m	114.8	106.3	56.8
ABW	888	m	176.1	164.3	86.7
ABWX	888	j	63.8	59.8	33.6
ABWY	888	j	63.7	59.0	32.8
ABX	888	m	151.0	144.3	73.9
ABXY	926	m	93.4	87.5	47.5
ABY	892	m	178.5	160.8	84.3
ABZ	365	f	96.6	89.8	48.3
AC	888	f	111.3	106.2	58.6
ACH^{2}	892	m	157.2	150.2	75.0
ACHI	72	m	173.4	158.8	80.8
ACHJ	72	f	173.3	168.4	84.3
ACHK	72	m	169.9	156.7	82.2
ACHL	72	j	103.6	97.5	54.9
ACHN	292	j	101.9	96.7	50.2
ACHO	613	m	191.8	168.2	83.8
ACHP	613	m	103.7	95.6	52.2
ACHU	945	m	166.5	153.7	79.6
ACHV	945	m	110.5	104.3	54.7
ACHW	621	m	186.0	176.3	86.0
ACHX	621	m	127.8	116.5	64.0
ACHY	621	m	115.4	109.0	57.3
ACI	839	m	173.1	160.1	80.8
ACIJ	613	m	104.4	95.7	54.1
ACIK	1720	m	113.3	109.3	55.7
ACIL	1720	m	105.7	100.4	50.5
ACIN	877	m	144.9	133.9	68.1
ACIO	877	m	164.4	154.5	79.4
ACIP	877	m	103.0	95.3	55.0
ACIU	877	m	122.9	118.5	60.6
ACIV	839	m	113.8	106.0	57.3
ACIW	839	m	125.0	116.6	62.3
ACIX	945	m	180.4	163.7	85.6
ACIY	345	f	192.8	183.9	89.6
ACJ	839	m	184.2	165.6	82.4
ACJK	345	m	128.5	123.8	67.1

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
ACJL	345	m	115.5	107.1	58.2
ACJN	168	m	202.2	184.1	87.7
ACJO	168	f	196.1	192.2	94.1
ACJP	72	f	114.3	108.7	56.3
ACJU	72	j	92.6	88.5	47.6
ACJV	72	f	122.8	116.1	62.1
ACJW	72	m	129.7	120.7	65.1
ACJX	72	f	138.9	129.5	68.7
ACJY	72	m	171.6	153.8	79.5
ACK	839	m	176.5	161.7	83.1
ACKL	345	m	123.6	116.3	61.5
ACKN	345	j	84.3	77.4	43.8
ACKO	345	m	173.0	159.0	81.9
ACKP	345	m	197.8	179.3	89.3
ACKU	365	m	182.4	164.0	82.7
ACKV	365	j	86.0	78.9	44.6
ACKW	365	m	147.3	138.6	71.9
ACKX	1720	f	118.0	112.0	58.7
ACKY	168	m	181.9	169.4	85.5
ACKZ	365	m	104.7	99.5	53.1
ACL	945	m	184.1	170.5	85.0
ACLM	345	m	120.2	110.0	58.0
ACLN	365	j	85.1	78.7	45.2
ACLP	345	m	175.4	162.7	82.1
ACLU	345	m	177.6	161.8	81.5
ACLUa*	365	f	89.9	85.5	45.6
ACLV	345	j	88.0	81.7	44.6
ACLW	345	j	89.2	84.4	45.4
ACLX	345	m	182.8	167.7	85.0
ACLY	168	f	135.5	132.3	68.4
ACN	945	f	184.5	178.0	88.1
ACNO	1720	f	185.2	182.0	90.2
ACNP	1720	f	121.2	117.9	62.1
ACNU	365	j	55.4	49.3	30.0
ACNV	613	j	67.9	60.6	34.5
ACNW	365	j	52.1	46.8	27.4
ACNX	365	j	53.2	48.0	27.5
ACNY	365	j	52.2	48.8	28.0
ACO	365	m	139.6	132.8	68.5
ACOP	168	m	107.2	100.0	53.3
ACOU	168	m	119.8	109.4	59.8
ACOV	168	j	74.8	68.4	39.6
ACOW	72	f	205.9	194.8	98.0
ACOX	72	f	183.2	176.0	89.3
ACOY	72	f	142.0	136.3	69.5
ACP	365	j	94.9	90.8	48.1
ACPU	72	j	98.2	91.5	49.4
ACPV	72	f	104.6	98.8	54.9
ACPW	72	m	128.3	119.2	62.8
ACPX	72	f	114.3	107.8	56.4

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm) Carapace length	Plastron length	Plastron width
ACU	365	j	94.5	86.8	47.3
ACUV	345	m	186.7	166.7	81.4
ACUW	345	j	49.7	46.4	26.4
ACUX	345	m	163.2	155.9	76.3
ACUY	345	f	126.5	120.0	63.7
ACV	365	j	97.7	91.1	50.6
ACVW	345	m	177.6	165.6	82.6
ACVX	345	j	85.0	77.7	43.7
ACVY	345	j	93.0	89.4	49.1
ACVZ	345	m	153.4	146.2	74.7
ACW	365	j	93.2	88.1	44.7
ACWX	365	j	81.5	75.1	41.5
ACWY	365	j	49.6	47.5	26.0
ACX	345	f	188.1	177.1	91.7
ACXY	365	m	103.2	97.7	50.4
ACYa	345	f	186.6	180.0	87.8
AH	888	j	115.6	109.7	58.9
AHI	345	m	177.4	163.9	81.4
AHIJ	945	f	178.3	171.7	91.2
AHIK	945	f	185.2	171.2	87.6
AHIL	945	m	172.0	159.3	81.3
AHIM	613	j	109.2	104.1	53.3
AHIN	877	f	191.7	182.9	93.5
AHIO	839	m	192.0	173.6	84.3
AHIP	839	f	175.3	172.5	86.2
AHIU	839	m	165.8	154.5	78.8
AHIV	839	m	196.7	179.7	84.5
AHIW	839	m	168.7	153.8	74.9
AHIX	839	m	163.3	149.9	75.5
AHIY	981	j	54.4	49.3	28.7
AHIZ	621	m	172.7	157.5	78.7
AHJ	345	j	87.4	79.7	45.3
AHJK	621	f	172.7	162.6	81.3
AHJM	613	f	139.7	129.5	68.6
AHJN	77	f	113.2	109.1	58.6
AHJO	877	m	166.7	154.6	77.1
AHJP	877	f	153.4	149.8	73.5
AHJU	877	m	173.1	161.9	80.3
AHJV	877	f	127.5	122.1	64.1
AHJW	877	f	132.4	127.9	64.9
AHJX	888	m	122.9	116.1	59.7
AHJY	839	m	153.4	146.7	70.2
AHK	345	j	86.7	79.4	46.1
AHKL	839	m	179.9	160.2	85.2
AHKN	839	m	157.2	147.8	77.3
AHKO	613	m	182.9	165.1	83.8
AHKP	613	m	175.3	160.0	76.2
AHKU	613	m	160.0	157.5	78.7
AHKV	613	m	180.3	165.1	83.8
AHKW	877	j	64.5	57.3	33.8

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm) Carapace length	Plastron length	Plastron width
AHKX	839	m	111.7	106.0	57.5
AHKXa	77	f	116.8	112.0	58.2
AHKY	72	f	203.2	193.0	91.9
AHL	345	j	88.4	82.7	47.1
AHLN	613	f	116.8	109.2	61.0
AHLO	839	m	177.6	163.0	83.0
AHLP	839	m	167.6	150.4	77.2
AHLU	621	m	177.8	165.1	78.7
AHLV	621	m	177.8	165.1	81.3
AHLW	621	m	129.5	119.4	63.5
AHLX	621	j	109.2	101.6	58.4
AHLY	613	j	104.1	99.1	53.3
AHN	1720	f	131.0	129.5	67.5
AHNO	72	m	178.0	169.1	82.4
AHNP	72	m	181.1	162.6	82.7
AHNU	72	m	162.6	154.1	77.8
AHNV	72	m	111.2	99.7	57.2
AHNW	168	m	179.3	168.6	84.4
AHNX	168	m	162.8	155.5	75.7
AHNY	168	m	188.3	175.3	84.7
AHNZ	72	j	92.9	86.2	47.2
AHO	1720	j	106.2	99.9	56.9
AHOP	168	m	190.9	173.7	83.4
AHOU	168	m	182.4	170.2	86.4
AHOV	168	m	153.7	147.6	69.6
AHOW	168	m	133.1	123.2	66.9
AHOX	168	m	117.7	110.6	58.4
AHOY	168	m	104.7	99.8	52.7
AHP	345	m	125.5	118.1	61.5
AHPU	72	m	163.9	155.3	78.6
AHPV	72	m	171.4	157.5	81.1
AHPW	72	f	197.1	193.3	92.3
AHPX	72	m	130.1	121.8	65.0
AHPY	72	m	117.7	110.2	56.9
AHU	365	j	100.3	96.9	53.6
AHUV	168	j	87.9	83.1	45.2
AHUW	292	f	89.7	81.3	43.7
AHUX	1720	m	172.7	154.9	78.7
AHUY	1720	m	180.3	165.1	76.2
AHUZ	839	f	182.9	172.8	86.3
AHV	365	j	95.0	88.6	47.0
AHVW	877	m	178.2	166.2	80.2
AHVX	877	m	153.1	140.0	70.4
AHVY	877	m	141.2	131.1	68.2
AHWX	877	m	100.8	92.8	54.1
AHWY	877	j	68.0	62.6	36.4
AHX	945	m	173.7	163.4	79.7
AHXY	839	m	166.9	158.1	81.1
AHY	945	f	106.9	104.4	55.0
AI	888	j	85.2	79.2	42.5

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
AIJY	877	f	126.4	118.2	61.1
AIJZ	877	m	106.0	95.0	55.4
AIK	365	m	149.0	140.5	72.9
AIKL	877	m	99.8	90.3	53.3
AIKN	72	f	201.6	193.5	93.4
AIKO	72	f	179.8	173.6	89.3
AIKP	72	f	114.2	108.6	59.7
AIKU	72	m	144.6	137.0	70.4
AIKV	72	j	95.2	91.3	50.6
AIKW	72	j	91.6	89.3	46.7
AIKX	888	m	194.2	175.7	93.3
AIKY	888	f	146.2	139.5	73.8
AIL	365	m	107.6	100.6	54.1
AILN	888	j	67.8	63.0	34.7
AILO	888	j	66.8	63.2	36.2
AILP	877	f	148.6	140.8	70.8
AILU	877	f	152.1	144.4	73.5
AILV	877	j	96.2	89.4	48.9
AILW	877	m	125.2	119.5	61.2
AILX	877	m	118.9	115.7	60.4
AILY	877	j	62.7	58.4	32.4
AIMZ	877	f	136.3	128.7	65.4
AIN	365	j	98.5	91.9	50.0
AINO	877	j	57.1	52.8	30.0
AINP	877	m	166.7	156.2	81.3
AIO	365	j	98.6	89.6	47.7
AIOP	877	j	63.9	57.6	34.0
AIOU	877	j	62.0	56.5	35.1
AIOV	877	j	63.0	56.7	31.2
AIOW	877	j	56.6	51.4	29.5
AIP	365	j	92.4	87.0	46.5
AIU	345	m	168.1	154.4	75.9
AIV	345	m	163.5	155.8	80.9
AIV	607	f	191.5	184.7	89.1
AIW	365	f	119.6	110.1	59.1
AIX	1720	f	184.6	175.3	86.1
AIY	1720	f	186.5	179.1	89.6
AIZ	345	f	176.4	173.4	85.2
AJ	1365	m	170.3	158.9	71.2
AJK	621	j	110.5	99.9	55.0
AJL	926	m	169.5	156.1	70.5
AJNa	365	f	200.4	189.5	92.7
AJO	365	f	156.3	148.2	75.4
AJP	392	m	177.1	165.0	83.9
AJU	365	j	85.0	77.9	43.3
AJV	365	j	79.5	72.7	42.0
AJW	381	f	171.2	166.0	85.5
AJX	345	f	183.1	177.5	88.8
AJY	345	m	133.6	122.2	62.7
AJZ	345	m	171.6	155.1	77.3

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm) Carapace length	Plastron length	Plastron width
AK	1365	m	179.8	161.5	83.3
AKL	345	m	143.8	136.9	71.4
AKM	345	m	183.0	168.2	82.2
AKN	345	m	182.8	166.2	84.0
AKO	345	m	150.0	143.4	77.0
AKP	345	f	187.3	178.0	86.4
AKU	345	m	186.7	175.7	89.1
AKV	345	j	82.0	76.0	42.8
AKW	345	f	136.1	128.7	69.4
AKX	365	j	61.5	57.6	34.4
AKY	365	f	193.6	185.5	89.7
AL	1365	f	186.0	173.9	86.4
ALM	1720	f	183.5	174.7	86.6
ALN	1720	m	167.6	154.9	77.6
ALO	1720	f	186.3	179.9	88.7
ALP	365	m	169.5	156.9	77.4
ALP	1720	m	173.7	162.1	81.5
ALU	365	m	174.2	159.5	79.1
ALV	365	m	173.1	154.9	78.1
ALW	365	m	181.6	165.7	84.9
ALX	365	m	105.7	98.8	50.2
ALY	365	j	65.9	62.4	34.3
AN	1365	f	183	173.1	86.6
ANO	365	j	102.8	97.6	53.0
ANOP	345	m	151.6	148.2	77.2
ANOU	345	j	88.2	81.9	45.3
ANOV	345	j	88.7	84.7	46.1
ANOW	345	j	79.9	75.2	40.7
ANOX	345	j	96.1	87.2	45.6
ANOY	345	j	88.8	82.6	47.2
ANP	365	f	191.0	184.3	87.3
ANPT	839	m	110.8	104.4	55.8
ANPU	839	f	124.2	120.8	64.2
ANPW	613	j	68.2	62.9	35.7
ANPX	613	m	182.9	166.3	84.1
ANUV	613	m	129.5	124.2	61.1
ANUW	613	m	124.5	119.6	62.4
ANUX	613	j	104.9	98.5	53.3
ANUY	72	m	173.8	156.8	79.5
ANV	365	f	173.2	163.3	86.9
ANVW	72	m	180.7	163.8	85.3
ANVX	72	m	123.1	115.1	60.3
ANVY	72	j	109.1	102.1	55.2
ANW	365	j	37.2	31.7	19.9
ANWX	72	j	107.5	102.4	55.2
ANWY	72	f	105.8	101.6	53.7
ANX	365	m	153.7	156.4	75.0
ANXY	72	f	143.1	133.5	73.5
ANY	365	f	181.6	175.9	86.5
ANZ	365	j	40.4	36.2	22.0

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
AO	1365	m	142.0	136.2	68.1
AOP	365	f	151.5	145.1	74.8
AOPU	72	m	95.4	87.7	49.9
AOPV	72	j	80.9	75.4	41.3
AOPW	621	m	120.3	111.9	62.9
AOPX	613	f	175.0	168.4	85.3
AOPY	945	m	106.8	101.3	55.8
AOU	365	f	147.2	137.6	71.5
AOUV	168	m	190.8	180.5	87.9
AOUW	292	j	89.3	84.8	43.9
AOUX	72	m	102.4	93.8	51.9
AOUY	72	m	99.5	92.8	50.5
AOV	365	m	125.5	114.7	62.8
AOVW	72	f	106.3	98.6	57.0
AOVX	621	m	174.3	157.8	80.8
AOVY	877	j	103.3	92.8	53.4
AOW	365	m	118.1	111.6	58.7
AOWX	945	f	122.2	115.0	61.1
AOWY	877	m	153.2	145.8	75.5
AOX	365	f	166.6	168.4	80.9
AOXY	839	f	187.8	182.2	88.3
AOY	365	m	111.1	100.2	55.8
AP	1365	m	164.1	148.3	80.4
APU	365	j	83.8	79.0	40.4
APUV	888	f	201.2	192.3	93.9
APUW	839	m	173.1	160.3	87.5
APUX	839	m	181.0	163.6	86.1
APUY	839	m	168.6	156.5	83.5
APV	365	j	91.5	83.0	47.4
APVW	839	m	194.9	177.0	91.3
APVX	839	m	124.8	118.3	61.6
APVY	839	m	110.5	103.8	53.9
APWX	839	m	162.4	147.5	78.3
APWY	839	j	89.3	86.1	48.8
APX	365	m	131.4	116.2	60.9
APXY	839	m	166.7	151.7	82.6
APY	365	m	112.2	104.6	55.5
AU	888	m	160.3	147.3	75.6
AUVW	839	m	105.6	98.1	51.9
AUVX	839	m	161.0	149.1	77.2
AUVY	839	m	145.8	136.0	70.0
AUWX	981	m	155.6	138.6	72.3
AUWY	839	m	162.0	149.8	79.4
AUXY	839	m	160.7	152.9	78.1
AV	888	m	170.7	151.2	80.3
AVW	365	m	108.6	99.8	52.8
AVWX	839	m	131.7	125.3	65.8
AVWY	839	m	114.1	107.8	56.3
AVX	365	m	111.6	104.8	53.5
AVXY	839	f	179.8	172.1	88.7

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
AVY	365	f	105.4	100.2	55.2
AW	888	f	192.3	182.2	91.4
AWX	365	f	95.5	92.5	50.8
AWXY	621	m	178.3	163.7	79.2
AWY	365	j	99.9	95.7	50.7
AX	888	m	186.9	175.6	88.9
AXY	839	m	121.0	112.8	58.5
AY	888	m	129.9	116.8	62.9
B	1365	m	x	x	x
BC'	crossing	f	190.1	181.4	90.4
BCH	365	j	83.7	77.3	43.7
BCHI	345	j	87.6	82.4	47.0
BCHJ	621	m	186.1	173.2	83.0
BCHJa	621	j	97.7	85.9	48.6
BCHK	621	j	67.2	62.3	35.7
BCHL	613	m	108.7	101.0	55.8
BCHN	72	m	173.2	159.0	79.8
BCHO	72	m	179.7	163.8	83.8
BCHP	72	m	164.0	157.3	75.2
BCHU	72	f	111.5	102.4	55.1
BCHV	72	f	130.1	124.4	67.9
BCHW	72	j	96.7	90.5	49.8
BCHX	72	f	108.4	103.8	54.7
BCHY	77b	j	83.9	78.0	42.7
BCI	365	j	80.5	75.2	43.0
BCIJ	72	f	174.4	165.7	83.2
BCIK	72	f	168.6	163.4	78.8
BCIL	72	m	176.2	161.9	84.1
BCIN	72	f	114.1	109.1	55.3
BCIO	72	f	192.7	182.1	91.4
BCIP	72	m	111.8	102.6	54.3
BCIU	292	f	110.8	106.1	55.3
BCIV	292	j	96.7	88.1	48.2
BCIW	292	f	96.8	91.5	47.5
BCIX	292	j	87.9	82.4	43.8
BCIY	292	j	80.2	76.0	42.1
BCJ	365	j	81.7	74.0	42.7
BCJK	292	j	83.2	77.6	42.7
BCJL	292	j	51.0	46.3	28.1
BCJN	292	j	74.4	71.9	39.2
BCJO	292	j	50.8	46.3	26.5
BCJP	292	j	52.7	48.4	27.2
BCJU	292	j	53.6	48.5	29.1
BCJV	292	j	49.9	45.9	26.3
BCJW	888	m	162.9	149.6	81.2
BCJX	621	m	177.1	161.4	83.7
BCJY	621	f	193.1	184.6	92.9
BCKL	77a	j	48.1	43.2	25.2
BCKN	1720	m	145.9	140.0	74.1
BCKO	292	m	186.4	166.3	82.1

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
BCKP	292	j	94.1	88.2	45.7
BCKU	72	f	130.7	124.3	67.2
BCKV	621	m	165.1	151.7	77.9
BCKW	621	j	71.8	63.6	34.8
BCKX	621	f	124.2	119.0	62.8
BCKa	365	j	77.7	69.6	41.4
BCKb	365	j	82.4	76.1	41.1
BCKc	365	m	186.7	178.4	87.3
BCL	365	j	63.4	60.1	35.5
BCM	945	m	190.4	173.1	84.6
BCN	877	m	112.4	94.8	51.5
BCO	888	j	40.1	36.6	21.2
BCP	945	m	173.4	159.5	84.8
BCU	888	m	144.9	133.9	70.0
BCV	892	m	154.6	142.4	76.0
BCW	945	m	178.1	168.6	76.7
BCX	945	f	196.4	187.4	87.5
BCY	621	m	152.0	138.3	73.0
BH	888	m	116.8	108.3	57.3
BHI	621	j	90.7	83.4	44.2
BHJ	621	j	106.5	98.9	53.1
BHK	613	m	155.4	145.6	75.1
BHL	613	j	94.3	89.0	49.7
BHN	345	m	157.7	144.7	73.7
BHO	345	j	82.2	77.9	43.9
BHP	345	f	177.4	174.7	82.7
BHU	926	m	156.2	144.8	76.1
BHV	839	m	166.3	155.6	79.0
BHW	877	j	97.6	86.9	51.0
BHX	613	m	177.9	161.6	82.8
BHY	613	j	105.6	96.9	52.9
BHZ	613	f	181.9	173.0	84.8
BI	888	j	96.6	88.8	48.9
BIJ	877	m	160.3	149.1	73.3
BIK	877	f	128.5	121.7	61.4
BIL	877	m	114.9	103.6	56.0
BILa	945	m	163.0	150.3	79.3
BIN	945	m	169.6	156.8	77.5
BIO	621		195.7	192.3	90.0
BIP	945	f	176.2	166.3	81.7
BIU	1720	m	153.8	141.6	72.0
BJ	888	j	118.8	112.6	58.9
BJ X	621	f	177.7	172.7	85.4
BJK	1720	m	131.8	125.2	67.2
BJL	345	m	180.9	160.7	80.5
BJM	1720	f	204.3	199.5	99.6
BJN	345	m	179.9	167.5	80.8
BJO	945	m	119.4	111.3	59.1
BJP	945	j	89.6	82.2	45.6
BJU	392	f	185.7	180.2	88.1

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
BJV	621	j	98.5	87.9	51.7
BJW	621	m	124.6	115.9	62.4
BJY	613	j	48.0	43.4	26.7
BK	888	f	192.9	186.8	91.6
BKL	613	m	170.5	155.2	81.2
BKN	613	m	174.1	166.2	82.2
BKO	1720	m	172.1	162.5	79.3
BKP	1720	m	171.6	160.8	77.7
BKU	365	m	100.8	95.5	49.1
BKV	365	m	179.1	166.6	83.3
BKW	365	m	166.9	152.8	74.7
BKX	365	f	142.0	136.2	69.9
BKY	365	m	113.7	102.4	55.3
BL[4]	888	f	194.6	184.6	96.8
BLU	365	f	98.6	92.2	49.2
BLW	365	f	121.8	116.5	60.3
BLX	365	j	42.9	39.0	22.9
BLY	365	j	79.9	74.0	39.9
BMN	365	j	50.7	47.0	26.1
BMO	365	m	175.7	160.9	80.6
BMW	345	j	47.0	41.1	25.4
BMZ	345	j	92.7	85.0	48.6
BN	888	j	121.9	116.0	63.0
BNO	365	j	53.0	46.7	26.6
BNP	365	j	66.7	61.0	36.3
BNU	365	j	50.2	47.0	27.2
BNV	365	m	162.0	152.6	72.5
BNVa	365	j	78.4	71.8	40.9
BNW	365	j	88.8	83.7	47.8
BNX	365	j	85.3	78.4	45.2
BNY[5]	374	j	73.7	70.7	38.8
BNZ	168	m	168.4	161.3	80.8
BO	888	m	168.9	153.3	76.1
BOU	365	j	60.7	52.5	30.3
BOV	365	j	71.6	61.2	38.5
BOW	365	m	117.6	111.5	59.7
BOX	365	j	31.7	29.2	18.6
BOY	365	m	113.2	105.0	55.7
BOZ	956	j	50.3	47.4	26.1
BP	888	m	135.1	129.0	67.2
BPQ	365	j	52.8	48.0	26.9
BPV	365	j	51.7	46.9	26.6
BPW	365	j	50.2	45.7	27.0
BPWX	365	j	53.4	49.4	29.2
BPY	365	j	55.3	50.7	29.6
BU	888	j	100.4	95.0	50.9
BUV	345	m	162.7	151.7	81.3
BUW	345	j	96.5	90.4	48.5
BUWX	345	j	88.4	80.6	47.5
BUX	345	j	92.9	86.7	47.7

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm) Carapace length	Plastron length	Plastron width
BV	888	m	121.5	110.4	60.3
BVW	365	j	51.8	46.6	28.6
BVX[a]	365	j	48.1	44.3	26.9
BVY	345	j	90.2	86.4	46.0
BVZ	345	m	166.2	155.6	79.6
BWX	345	m	127.1	116.6	63.6
BWY	345	f	194.7	189.8	96.6
BWa	888	f	180.3	172.6	80.8
BWb	888	f	123.7	120.1	65.1
BX	888	j	81.3	77.4	44.2
BXY	345	j	90.9	84.2	47.7
BY	888	j	86.5	78.9	45.5
C	1366	j	114.6	107.8	56.0
CH	888	f	185.1	178.8	89.4
CHI	365	j	77.6	69.4	39.5
CHJ	365	j	72.1	67.5	38.2
CHK	345	j	81.1	75.9	41.0
CHL	345	j	106.7	102.1	54.5
CHM	345	f	178.1	170.7	84.7
CHN	345	m	128.9	122.9	65.9
CHO	345	m	111.2	109.2	58.2
CHP	345	m	163.6	155.0	78.6
CHU	345	f	172.7	165.5	85.3
CHV	345	m	166.0	152.4	74.6
CHW	345	m	185.5	171.0	85.1
CHX	345	m	167.2	158.7	79.5
CHY	345	m	172.6	161.6	80.7
CI	888	j	103.1	94.8	52.4
CIJ	345	m	165.7	155.1	78.0
CIK	345	m	173.1	159.4	76.7
CIL	613	f	144.0	137.5	71.2
CIN	613	m	161.7	149.0	76.0
CIO	613	x	113.9	103.9	56.0
CIP	621	x	48.6	43.7	26.2
CIU	1720	j	96.7	89.1	47.2
CIV	1720	j	97.5	95.5	53.1
CIW	877	f	182.2	174.5	84.7
CIX	839	m	144.5	137.0	71.0
CIY	839	m	112.3	100.4	52.8
CIZ	365	m	179.4	159.5	78.7
CJ	888	j	86.5	78.5	43.7
CJK	877	f	187.0	180.4	87.0
CJM	1720	m	189.0	167.5	81.9
CJNa	877	f	145.3	138.5	71.6
CJO	877	f	133.0	127.4	68.1
CJP	877	j	104.2	92.8	54.6
CJU	877	f	133.9	120.0	67.1
CJV	945	m	187.3	172.7	86.2
CJW	945	f	197.3	193.1	94.3
CJX	365	m	118.1	112.5	57.6

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
CJY	365	m	181.8	167.8	80.4
CJZ	839	m	130.5	118.3	63.8
CKL	365	m	179.3	168.2	81.1
CKN	365	m	135.6	128.6	61.3
CKO	365	j	90.9	84.3	46.1
CKP	345	m	165.6	150.5	79.6
CKU	345	m	171.2	155.8	82.9
CKV	345	m	187.8	170.6	86.1
CKW	345	m	178.3	163.1	82.1
CKX	345	m	178.4	163.7	83.3
CKY	345	m	168.3	152.0	78.5
CKZ	613	m	121.5	111.4	58.7
CKa	888	m	175.4	157.8	75.9
CKb	888	m	104.9	98.3	55.2
CL	888	m	147.4	135.1	69.3
CLN	839	m	118.2	109.6	57.2
CLO	345	m	201.2	182.5	90.3
CLP	345	m	171.2	154.4	80.1
CLU	345	m	141.0	130.5	67.6
CLV	345	m	147.6	138.4	72.1
CLW	621	f	175.7	170.1	84.8
CLX	1720	m	188.3	177.3	84.2
CLY	877	f	128.5	121.2	62.9
CM	888	m	161.0	145.7	73.6
CN	888	m	173.3	161.3	80.4
CNO	345	m	125.5	117.3	62.3
CNP	345	m	101.4	91.7	50.9
CNU	345	j	81.8	77.4	46.1
CNV	877	m	186.6	170.1	83.1
CNW	877	m	162.1	149.1	81.7
CNX	877	f	160.9	151.8	80.6
CNY	877	f	167.4	155.5	82.3
CNZ	877	m	191.6	175.2	84.3
CO	888	m	141.2	131.6	70.0
COP	877	f	134.4	129.8	69.3
COU	345	j	89.0	83.3	46.3
COVa	877	f	130.4	123.5	65.9
COW	877	f	127.2	121.0	65.4
COX	877	f	129.9	123.3	67.0
COY	877	f	127.6	122.8	66.4
COZ	839	m	191.8	174.7	84.7
CP	888	f	131.8	124.4	64.9
CPU	877	j	128.8	122.4	62.7
CPV	877	m	126.6	120.4	60.0
CPW	621	j	55.5	51.1	27.8
CPX	621	f	201.8	187.2	91.1
CPY	621	m	178.8	165.5	83.5
CPZ	621	m	150.7	137.1	69.2
CU	888	m	141.6	133.9	67.7
CUV	365	f	180.5	177.0	86.2

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
CUW	365	f	151.3	144.2	74.4
CUWY	365	f	135.4	126.1	66.0
CUX	365	j	89.1	84.2	47.3
CUY	365	j	93.0	85.9	48.0
CV	888	f	166.4	157.9	80.2
CVW	345	m	178.5	162.2	79.4
CVX	345	m	168.7	153.0	80.9
CVY	345	m	148.1	135.8	70.5
CW	888	f	188.9	178.2	86.6
CWX	1720	m	112.7	103.7	54.3
CWY	345	j	101.3	92.9	51.0
CX	888	m	133.2	123.6	62.1
CXY	1720	j	112.4	103.8	54.8
CY	621	m	175.9	160.1	80.6
DJM	345	f	107.1	102.4	54.4
EFTU	621	j	93.4	86.1	49.1
HI	621	f	147.2	142.9	73.7
HIJ	345	m	171.8	152.9	74.7
HIJL	x	j	82.5	80.5	42.1
HIK	345	m	171.4	160.2	79.6
HIL	345	f	180.1	174.5	89.2
HIN	345	f	193.0	179.6	86.4
HIO	345	j	76.0	69.1	40.6
HIOP	345	m	170.9	155.3	77.1
HIPb	945	m	167.2	158.7	79.4
HIU	345	m	180.3	164.6	84.7
HIUV	621	m	168.6	160.2	78.6
HIV	345	m	186.1	172.9	88.6
HIW	345	m	128.4	119.1	66.0
HIWX	345	m	186.5	174.6	86.6
HIX	945	f	125.0	120.1	63.5
HIY	72	f	116.0	112.7	61.6
HIY	613	m	184.7	164.3	83.3
HJ	621	m	138.0	127.7	65.4
HJK	877	j	95.0	83.5	49.8
HJL	877	j	131.3	121.2	63.2
HJN	877	m	115.5	107.4	58.1
HJO	877	f	122.3	117.5	62.8
HJP	888	m	113.4	107.1	54.8
HJU	926	f	102.8	95.3	53.2
HJV	613	m	107.6	99.6	51.2
HJW	72	m	177.3	166.0	81.9
HJX	613	m	137.3	125.1	66.2
HJY	72	f	168.5	155.1	80.6
HK	621	m	108.3	99.1	55.5
HKL	72	f	119.1	112.6	62.1
HKN	72	m	122.0	116.0	58.6
HKO	72	m	124.6	115.4	60.0
HKP	72	m	114.7	110.4	59.3
HKU	72	m	112.0	103.7	54.5

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm) Carapace length	Plastron length	Plastron width
HNP	168	m	169.2	159.1	80.0
HNV	888	j	92.2	87.3	45.7
HNW	365	m	125.4	115.1	61.9
HNX	365	m	106.9	98.6	55.3
HNY	365	f	91.3	85.7	46.8
HO	888	f	167.7	162.0	81.4
HOP	888	f	133.1	123.9	68.2
HOU	72	f	115.0	112.7	60.5
HOV	72	f	110.8	105.3	57.2
HOW	72	m	102.4	96.1	53.4
HOX	72	f	113.1	107.0	57.4
HOY	345	m	169.8	161.1	80.4
HP	621	j	97.2	87.0	49.8
HP	607	j	70.0	64.4	37.3
HPU	72	j	103.8	98.8	53.8
HPV	72	f	114.4	107.0	56.9
HPW	72	f	88.9	85.4	43.9
HPX	72	j	98.2	91.0	50.7
HPY	72	j	87.5	83.8	45.2
HU	607	j	79.2	75.3	40.0
HUV	72	j	84.5	78.1	44.4
HUWb	168	m	194.3	182.6	91.3
HUX	168	m	170.1	166.4	77.0
HUY	168	m	108.1	100.1	53.3
HV	1720	m	167.5	160.6	83.8
HVW	345	f	184.1	180.6	87.2
HVX	345	j	93.0	86.6	48.1
HVY	168	m	149.8	138.3	73.4
HVa	888	j	132.6	124.4	64.0
HW	607	j	77.1	70.3	38.4
HWX	168	f	145.6	137.3	71.7
HWY	168	f	126.7	119.2	65.0
HX	621	m	136.8	125.3	64.4
HXY	292	m	138.5	128.5	68.8
HY	621	j	87.4	77.8	46.4
Ha	888	f	212.8	196.8	98.8
I	888	m	163.2	150.6	77.0
IJ	365	m	109.6	98.2	55.1
IJK	406	f	198.3	186.7	94.9
IJL	345	j	80.4	73.9	41.6
IJM	345	m	156.7	141.5	77.9
IJN	345	m	114.9	108.5	56.1
IJO	345	f	104.5	99.4	55.3
IJP	345	j	79.7	72.8	41.9
IJU	345	m	123.9	117.5	62.0
IJV	345	m	124.8	117.0	64.1
IJW	345	m	121.0	114.6	60.2
IJX	345	m	156.2	145.0	75.6
IJY	374	j	90.7	84.9	46.3
IJZ	406	m	177.8	160.7	82.0

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
IK	365	m	168.1	157.7	77.5
IKL	365	f	137.6	129.7	67.6
IKN	365	m	128.5	118.7	64.5
IKO	365	m	171.8	159.9	84.5
IKP	365	f	86.6	81.4	46.6
IKU	365	m	140.0	130.0	68.6
IKV	365	f	88.4	81.8	45.8
IKW	72	j	91.5	85.3	45.8
IKX	72	m	116.9	99.8	53.4
IKY	72	j	112.3	108.5	56.8
IL	607	j	105.9	101.8	53.4
ILM	877	f	149.7	140.7	71.0
ILN	292	j	86.4	80.6	44.1
ILO	292	j	88.7	81.4	47.0
ILP	292	j	85.5	78.1	43.2
ILU	292	j	76.6	70.2	40.3
ILV	877	j	95.7	84.0	50.5
ILW	888	m	168.0	156.5	79.4
ILY	345	m	181.4	166.7	83.3
IM	365	m	112.4	103.3	57.9
IMZ	945	m	167.8	155.4	76.0
IN'	607	j	97.3	92.5	50.0
INO	72	m	101.1	96.7	51.0
INP	72	f	97.6	89.8	48.7
INU	72	m	114.1	104.6	56.2
INV	72	f	122.1	116.5	62.5
INW	72	j	98.9	91.6	50.6
INX	72	m	112.4	103.5	55.6
INY	72	m	117.7	110.3	57.8
IO	345	j	108.3	100.2	50.7
IOP	72	m	125.7	117.6	62.5
IOU	72	j	89.8	85.3	46.6
IOV	72	m	122.4	112.4	60.2
IOW	72	j	95.8	88.9	48.8
IOX	168	m	193.2	174.1	86.6
IOY	168	m	124.8	116.4	59.2
IP	365	j	100.6	95.5	51.1
IPU	168	f	152.9	148.7	72.2
IPV	168	f	108.3	103.4	57.6
IPW	168	m	164.8	156.2	75.6
IPX	168	j	114.2	108.7	59.2
IPY	168	m	156.6	147.3	77.9
IU	888	j	92.4	84.6	47.4
IUV	877	j	101.4	94.4	51.7
IUW	877	f	128.5	120.5	62.7
IUX	877	m	114.6	107.0	55.2
IUY	877	m	126.0	119.4	60.0
IV	892	m	132.9	121.6	65.8
IVW	168	f	110.7	103.6	55.5
IVX	292	j	85.0	75.5	43.2

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
IVY	877	f	132.2	127.8	66.2
IW	892	j	105.6	97.7	51.6
IWX	877	f	121.0	109.3	59.4
IWY	877	f	130.9	121.7	62.0
IX	892	m	139.0	134.6	69.8
IXY	621	j	100.2	91.1	51.3
IY	839	m	125.9	117.3	63.2
JK	621	m	126.7	118.3	63.4
JKL	888	m	128.9	123.4	63.4
JKN	888	j	56.4	51.4	29.3
JKO	945	f	190.4	181.4	91.0
JKP	621	m	169.7	160.3	78.7
JKU	621	m	172.8	155.8	78.5
JKV	621	f	179.9	173.7	89.0
JKW	621	m	183.5	171.6	83.9
JKX	621	f	134.2	130.1	65.1
JKY	621	m	126.8	120.3	61.5
JL[a]	nesting	f	191.5	182.4	x
JLN	621	j	97.7	88.6	49.7
JLO	613	f	190.8	181.6	90.3
JLP	1720	m	175.0	164.0	81.0
JLU	345	m	153.5	148.5	75.0
JLUa	1720	f	203.9	197.2	94.0
JLV	345	m	174.4	161.3	84.0
JLVa	1720	f	134.1	128.0	69.4
JLW	345	j	100.5	94.8	50.5
JLX	345	j	85.9	81.0	45.8
JLY	345	j	83.5	77.9	43.5
JM[a]	crossing	f	215.7	205.3	98.3
JMZ	345	j	92.8	87.6	47.4
JN	621	j	89.8	80.9	47.4
JNO	345	j	89.6	82.7	47.0
JNP	406	m	135.6	126.7	62.4
JNU	365	m	116.8	110.9	58.3
JNV	365	m	179.8	166.1	80.5
JNW	365	f	118.2	111.3	58.3
JNX	365	m	119.6	107.0	59.1
JNY	365	j	62.5	59.5	34.2
JO	888	f	159.1	152.4	74.0
JOP	72	f	173.1	166.2	82.9
JOU	72	m	179.0	167.4	83.7
JOV	72	f	196.0	191.9	91.2
JOW	72	f	135.4	130.3	68.3
JOX	72	f	109.4	105.1	54.4
JOY	72	m	100.1	94.2	52.6
JP	888	f	156.4	150.1	74.2
JPU	72	j	99.1	95.4	51.7
JPV	72	f	105.9	100.0	52.8
JPW	72	f	108.2	104.2	55.9
JPX	72	j	88.4	83.1	46.8

	Original capture		Shell measurements (mm)		
Turtle code	location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
JPY	72	j	99.3	91.7	49.4
JPY	292	f	104.3	92.5	51.8
JU	888	m	158.9	146.7	73.5
JUV	345	j	82.7	77.8	43.0
JUW	345	j	89.9	80.6	47.2
JUWX	345	j	51.5	47.8	27.7
JUX	345	j	84.2	78.1	44.7
JV	888	m	172.0	152.4	78.9
JVW	292	j	91.7	82.6	45.5
JVX	292	j	85.7	76.6	41.8
JVY	621	m	124.3	116.1	61.9
JW	345	m	165.6	153.4	80.2
JWX	345	j	42.2	38.0	22.2
JWY	345	j	44.1	40.2	24.1
JX	345	f	123.7	121.6	63.7
JXY	621	m	132.4	122.9	64.1
JYa	345	j	88.2	82.9	45.3
JZ	345	f	188.2	178.6	86.1
Ja	888	j	110.8	104.3	56.5
K	888	m	171.9	159.9	80.2
KL	926	m	187.8	168.5	86.1
KLN	345	j	105.9	100.2	55.2
KLO	345	f	178.2	171.9	86.3
KLP	345	m	202.0	184.5	89.3
KLU	345	j	91.6	84.6	48.1
KLV	345	j	93.6	87.8	48.5
KLW	345	m	189.4	171.5	88.3
KLX	345		174.8	159.0	82.9
KLY	613	j	112.9	104.5	56.1
KMO	345	m	191.0	173.2	85.2
KN	926	f	189.1	184.0	90.6
KNO	613	m	163.1	154.8	77.4
KNP	72	f	120.0	114.5	62.5
KNU	72	f	120.5	111.5	60.5
KNV	292	m	121.9	113.0	59.5
KNW	72	f	99.2	93.7	51.1
KNX	72	f	122.2	116.8	60.3
KNY	72	f	141.2	142.4	69.5
KO	621	j	100.8	94.1	52.9
KOP	292	j	89.0	82.8	46.1
KOV	292	j	87.0	79.7	43.9
KOW	168	f	200.2	195.5	94.6
KOX	168	f	181.3	176.4	88.0
KOY	168	m	159.5	150.2	75.4
KP	607	m	101.9	99.6	49.0
KPV	168	m	126.8	119.1	61.9
KPW	168	m	123.1	114.1	61.3
KPX	168	f	111.5	106.6	58.2
KPY	168	j	84.9	78.1	43.5
KU	345	j	77.2	72.2	39.9

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
KUV	877	m	154.4	141.6	70.3
KUW	839	m	171.0	162.5	81.0
KUX	168	m	154.1	146.8	71.7
KUX	926	m	183.0	166.7	79.6
KUY	365	m	94.1	85.6	45.7
KV	365	f	192.9	184.4	90.1
KVW	1720	m	170.9	159.6	79.6
KW	365	m	18.7	99.0	54.8
KWX	168	m	142.4	133.7	69.5
KWY	168	f	182.5	177.1	89.5
KX	365	j	91.5	84.5	46.0
KXY	345	f	187.1	182.4	90.1
KY	365	f	188.0	176.0	84.2
L	888	m	185.6	175.3	86.4
LMN	345	m	146.7	134.1	66.8
LMO	839	m	186.6	169.7	84.1
LMU	345	f	199.0	185.1	95.1
LMV	345	m	172.7	160.9	84.8
LMW	945	m	187.3	169.9	84.4
LMX	621	m	173.4	160.4	82.0
LMYZ	945	f	127.2	119.0	65.4
LMZ	345	m	167.9	152.6	79.4
LN	345	j	96.8	92.2	53.1
LNO	345	m	179.7	164.9	81.8
LNP	345	f	172.8	164.0	80.2
LNPU	345	m	126.9	121.2	63.8
LNUa	168	f	106.5	102.3	53.2
LNUb	877	m	116.3	109.7	56.3
LNV	839	f	179.6	172.3	85.0
LNW	945	m	163.6	150.8	78.2
LNX	945	m	174.3	162.1	82.8
LNY	345	m	179.7	164.9	85.4
LNZ	345	j	103.4	97.0	51.3
LO	345	j	88.6	84.5	47.0
LOP	292	j	79.2	70.7	40.7
LOU	621	j	64.1	58.6	34.2
LOV	621	j	65.7	57.6	33.2
LOW	1720	m	189.1	176.6	87.7
LOX	888	j	106.5	99.9	54.9
LOY	888	j	100.2	97.2	49.9
LP	345	j	88.7	83.3	47.0
LPU	345	m	127.2	119.6	61.7
LPV	345	f	113.3	108.1	57.1
LPW	621	m	171.6	165.6	86.6
LPX	345	j	93.4	87.9	49.5
LPY	621	m	129.7	121.9	63.1
LU	365	m	191.3	171.7	88.4
LUV	345	f	93.6	87.1	48.4
LUW	345	m	158.4	143.0	77.2
LUX	72	f	131.1	125.7	65.4

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
LUY	72	m	110.5	100.6	56.7
LV	365	f	103.6	98.3	53.2
LVW	345	j	91.5	84.8	46.8
LVX	72	f	206.7	200.6	97.2
LVY	72	f	112.5	106.6	56.7
LW	365	m	174.2	158.2	81.7
LWX	72	f	107.8	102.9	56.1
LWY	168	f	148.5	146.9	75.7
LX	365	f	108.7	103.3	56.7
LXY	72	m	122.1	116.7	60.8
LY	365	m	93.3	88.5	47.5
MWZ	345	m	171.8	154.3	76.9
N	1365	f	x	x	x
NO	945	m	152.9	147.2	74.0
NOP	168	f	118.8	111.5	59.5
NOU	168	f	99.2	96.8	51.6
NOV	613	m	186.9	169.8	88.0
NOW	613	f	118.5	110.7	60.8
NOX	613	j	67.9	62.4	33.6
NOY	345	f	135.1	131.0	70.0
NOZ	945	f	118.0	110.4	58.1
NP	888	m	157.8	150.8	70.8
NPV	945	m	101.4	92.6	49.4
NPW	345	f	165.8	156.3	81.8
NPX	345	m	135.0	126.3	64.2
NPY	345	j	87.3	80.2	44.6
NU	839	m	111.7	103.6	54.5
NUV	621	f	116.6	108.8	56.8
NUW	613	f	212.1	200.0	102.3
NUX	613	m	163.4	152.6	76.7
NUY	77	j	98.7	93.1	47.2
NUZ	345	f	99.5	96.4	54.5
NV	839	m	169.2	154.2	84.4
NVW	345	j	100.7	93.7	50.5
NVX	345	j	82.0	73.9	44.8
NVY	621	j	95.4	89.1	50.3
NW	839	m	143.6	137.9	71.0
NWX	72	f	180.2	171.8	84.9
NWY	77	j	84.0	80.3	45.0
NXY	72	m	134.4	124.2	66.1
NXa[10]	839	m	134.7	119.3	64.9
NXb	345	m	183.1	168.1	80.5
NY	345	j	80.0	75.2	42.5
O	888	m	175.4	168.5	82.7
OPU	72	m	196.7	179.4	91.3
OPV	72	f	203.3	192.2	97.8
OPW	72	m	176.6	166.2	85.6
OPX	72	m	173.0	154.4	76.2
OPY	72	m	145.7	135.6	72.3
OU	345	j	85.7	80.1	41.8

Turtle code	Original capture location (pond no.)	Sex	Shell measurements (mm)		
			Carapace length	Plastron length	Plastron width
OUV	168	j	88.4	85.7	45.5
OUW	168	m	118.7	116.5	56.9
OUX	168	m	116.7	105.6	57.8
OUY	168	f	106.3	101.7	53.4
OV	345	m	103.2	94.8	51.2
OVW	72	j	107.6	102.7	52.8
OVX	168	m	175.4	164.8	82.3
OVY	168	m	175.9	159.9	80.3
OVZ	168	f	190.7	177.7	89.9
OW	392	f	185.6	173.9	83.6
OWX	168	m	185.0	172.2	86.2
OWY	168	m	128.6	118.6	63.5
OX	365	m	179.9	162.6	82.8
OXY	945	m	154.8	144.7	73.4
OY	945	f	183.1	180.1	88.1
OZ	621	m	165.1	151.4	74.1
P	1365	m	x	x	x
PU	365	m	111.6	103.3	53.6
PUV	345	f	189.1	181.1	88.2
PUW	345	m	163.2	155.0	74.3
PUX	345	m	94.9	87.1	49.1
PUY	345	j	48.3	45.1	26.6
PV	365	j	86.9	80.6	46.3
PVW	345	j	89.7	84.0	46.1
PVX	345	m	173.1	162.6	82.9
PVY	345	m	161.5	154.4	70.6
PWX	345	f	145.4	141.2	73.6
PWY	345	j	84.7	79.5	41.2
PX	365	m	106.1	96.5	53.7
PXY	345	m	199.2	177.0	86.8
PY	945	m	163.4	149.2	77.7
PZ	365	j	98.6	84.0	45.6
U	1365	j	x	x	x
UV	945	m	122.3	114.7	63.2
UVWY	888	m	183.8	168.7	81.3
UVX	345	m	187.4	173.2	86.3
UVY	345	m	175.3	159.5	81.8
UVZ	345	j	108.9	101.8	53.9
UW	888	m	115.7	111.8	59.1
UWX	345	j	90.9	85.6	46.5
UWY	345	m	131.8	123.6	66.4
UX	888	f	190.3	181.4	92.9
UXY	345	m	94.4	88.3	49.7
UXYa	345	f	203.6	189.7	89.0
UY	888	m	194.3	174.0	85.4
UZ	945	j	117.5	111.4	60.0
V	888	j	117.1	109.6	57.7
VW	839	m	176.5	155.5	78.3
VWX	345	f	130.0	123.0	67.9
VWY	345	f	193.7	184.7	95.0

			Shell measurements (mm)		
Turtle code	Original capture location (pond no.)	Sex	Carapace length	Plastron length	Plastron width
VWZ	345	j	112.4	105.7	54.1
VX	839	m	123.0	116.6	61.4
VXY	345	j	93.8	87.4	48.0
VY	621	j	42.8	39.3	22.9
VZ	621	f	191.0	184.7	90.7
VZ	892	j	101.1	93.3	51.5
W	888	j	111.4	103.2	56.7
WX	892	m	160.6	154.9	78.0
WXY	345	j	78.9	72.5	39.4
WXYa	621	m	x	178.9	87.5
WY	892	f	117.5	113.6	57.7
WZ	365	j	90.1	81.8	43.3
X	888	f	121.3	116.3	60.4
XY	839	f	146.4	141.6	69.7
XZ	345	m	190.0	164.9	82.1
Y	888	j	94.2	87.4	47.4
YZ	945	m	173.0	152.7	73.7

* lower case letters in turtle codes are not part of the code but shown to distinguish between turtles accidentally marked with the same codes.

1=recaptured in Pond 345.
2=recaptured in Pond 839.
3=crossing Highway 93 next to Crow Creek bridge.
4=recaptured in Pond 877.
5=recaptured in Pond 365.
6=recaptured in Pond 345.
7=recaptured in Pond 365.
8=nesting next to Pond 1854.
9=crossing Ninepipe Road at south end of dam.
10=recaptured in Pond 886.