Traffic Related Mortality and the Effects on Local Populations of Barn Owls *Tyto alba*

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Abstract: We are currently examining traffic induced mortality of barn owls and its impact on their population growth. This paper presents results of data collected from weekly surveys at three sites along two California highways in rural areas from May 25, 1995 to November 26 1995. For each owl, we recorded spot of collection, adjacent habitat and current weather conditions. Age and sex of the collected owls were determined by differences in molt patterns, plumage and body size. There was a significant difference in the number of collected owls between the three sites. Differences in the adjacent habitat appear to be responsible for the distribution of fatalities among the three sites. Of the 227 owls collected, 61% were juveniles and 39% were adults. There was a significantly skewed sex-ratio: 74% of the collected owls were females. Differences in local population demography and/ or vulnerability may result in a greater number of both female and hatching year owls collected. Finally, we constructed a life history model in order to assess the impact of traffic related mortality on the growth rate of these populations. Results from the model predict that when about 48% of adult mortality is due to traffic or 27% of the hatching year mortality is due to traffic, the population growth rate drops below one and the population is in decline.

Introduction

Our transportation system kills an unknown number of the wildlife that utilize such corridors. Increased traffic flow moving at greater speeds may be a major factor in traffic fatalities of many species of birds (Hodson and Snow 1965). Nocturnal birds and mammals seem to be especially at risk of collision due to temporary blindness caused by lights of the vehicles (Schulz 1986). The foraging habit of owls, swooping down across roads in the direction of the oncoming lights (Hodson 1962), makes them highly vulnerable to vehicular collisions. Traffic collisions has been shown to be a significant factor of mortality for many species of owls (Glue 1971, Glue 1973, Hodson and Snow 1965, Newton et al. 1991, Ilner 1992, Taylor 1994).

Due to their preference of foraging in grassy habitat (Goertz 1964, Bloom 1979, Bunn et al 1982, Colvin et al 1984, Marti 1988, Hume 1991, Taylor 1994), barn owls (*Tyto alba*) may be especially vulnerable to traffic collisions along roads that pass through rural and agricultural areas. From roadside fence posts, barn owls can attack the prey directly or fly to a height of about 3 meters and then drop to their rodent prey (Taylor 1994). Barn owls most frequently locate prey by the slow flight method from a height of 1-3 meters (Taylor 1994), which can put them in a direct path of fast moving vehicles while hunting along highways.

Barn owls, the most widespread of all owls in the world, (Burton 1984), have experienced declines in coastal southern California (Bloom 1979), some midwest states (Colvin et al. 1984) and parts of Europe (Burton 1984). Based on Christmas counts from 1952-56 to 1975-77, the barn owl had expanded its range along the Pacific coast states of California, Oregon and Washington (Stewart 1980). Declines in southern California have been attributed to changes in land use (Bloom 1979) but little is known about the current status of barn owl populations in the central valley of California. A road recovery study in the California central valley suggests that traffic related mortality is the major cause for the death of barn owls (Schulz 1986). No published studies in the US have quantified the age and sex of barn owls killed by vehicular collision. In this study we quantify the number, sex and age distributions of barn owl traffic fatalities and relate this information to habitat characteristics and time of year. We also construct a life history model to give additional information on the impact of traffic related mortality on California barn owl populations.

Methods

We surveyed three sections of freeway, covering 236 km, from May 25, 1995 to November 26, 1995 (Figure 1). These four lane divided highways were surveyed in north and south bound directions. The south site, along Interstate 5, extends from the Sacramento city limits in Sacramento county into San Joaquin county. The middle site is between the cities of Davis and Woodland along Highway 113 in Yolo county. The north site is along Interstate 5, from the highway 113 junction, and extends north to the city of Williams in Colusa County.

In order to obtain an accurate representation of location and date of collected owls, all barn owls (50) found in a preliminary survey were removed from the study area on May 20-21. For every collection, we recorded the location to the nearest .08 km and adjacent habitat on both sides of the highway. Habitat surveys measured to the nearest 0.08 km were conducted on July 30, 1995 and March 9, 1996 to determine habitat type along highway study sites.

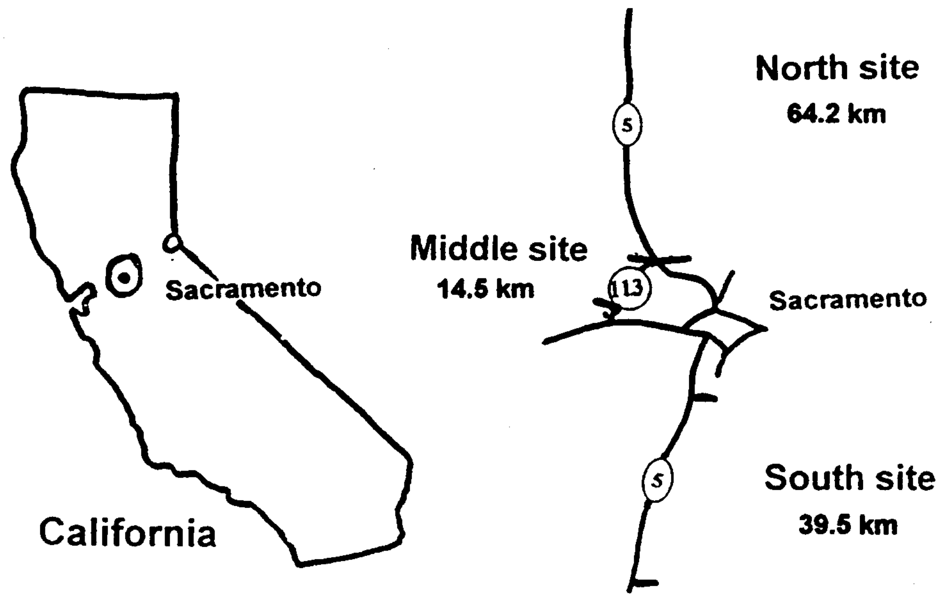

Figure 1. Study area located in the Sacramento area. The south and north site were along Interstate 5 and the middle site was along highway 113.

In the lab the birds were aged by wing molt patterns and then sexed by differences in plumage and size using a method derived by Bloom, P.H. (pers comm). Confirmation of sex, on all owls in suitable condition, was done by internal examination for testes or an ovary. Examinations provided positive identification of the sex on 51/53 (96 %) owls internally inspected. Nightly traffic flows in the three sites were obtained by monitoring stations during the hours of 8:00 PM and 5:00AM. (Caltrans 1995). Weather conditions were obtained by the NOAA Reference Climatological station operated by the Department of Land, Air and Water Resources, University of California, Davis (UCD).

Results

Habitat During the 27 weeks, barn owls were the most fequently collected bird (Table 1). There was a significant difference (X^2=126, df=2, p < .001) in the 227 collections of barn owls between sites; 155 in the south site, 6 in the middle site and 66 in the north site (Figure 2). Adjacent habitat varied between the sites. There was a significant difference in barn owls collected in the adjacent habitat (Table 2, X^2 = 47, df = 5, p < .001). Barn owls collected in pasture/open habitat are over-represented and collections in rotated crops habitat are under-represented (Figure 3).

Table1. Total number of bird species collected. Barn owls were 80% of the birds collected.

Species		Number
Barn Owl	*Tyto alba*	227
Burrowing Owl	*Athene cunicularia*	1
Great Horned Owl	*Bubo virginianus*	6
Short-eared Owl	*Asio flammeus*	1
Northern Harrier	*Circus cyaneus*	2
Red-shouldered Hawk	*Buteo lineatus*	1
Red-tailed Hawk	*Buteo jamaicensis*	12
White-tailed Kite	*Elanus caeruleus*	1
American Widgeon	*Anas americna*	1
Black-crowned Night-Heron	*Nyctanassa violacea*	1
Cliff Swallow	*Hirundo pyrrhonota*	1
Mallard	*Anas platyrhynchos*	12
Ringed-neck pheasent	*Phasianus colchicus*	17

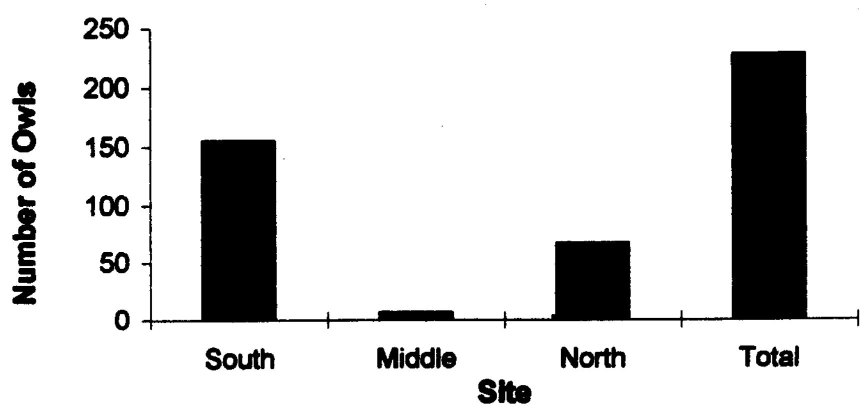

Figure 2. Number of collected barn owls with an average on South site of 5 /km, on Middle site of .5 /km and on North site of 1.3 /km.

Table 2. Percent habitat adjacent to spot of collected owls for each of the sites.

Site	Pasture/open	Rotated crops	Vineyard	Orchard	Dairy	Other
South site Habitat %	53	28	10	1.3	2.4	5.3
Collections %	64.1	20	3	2	4.8	6.1
Middle site Habitat %	3.6	72	2	1	0	21.4
Collections %	25	50	0	0	0	25
North site Habitat %	7.2	63.7	1.2	11	0	16.9
Collections %	8.3	61.5	1.5	9.8	0	18.9

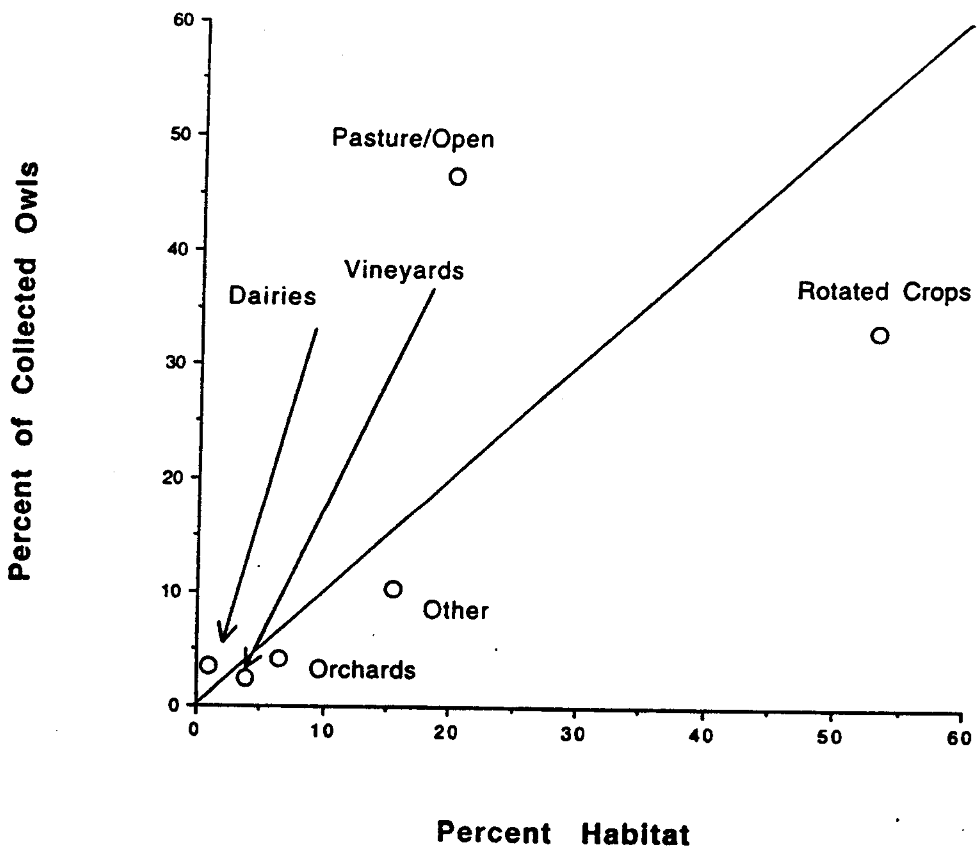

Figure 3. Percent of collected barn owls relative to the percent of adjacent habitat for the whole study area. If the spot of collection was random and not influenced by habitat all points should line up close to the diagonal line. All points to the left of the diagonal line are over-represented and those points to the right are under-represented.

Temporal Pattern There was a significant difference in the average daily collection for each month during the study ($X^2 = 13.96$, df = 6, $p < 0.05$). The average collection by month was: May - 1.43 /day, June - 0.98 /day, July - 0.64/day; August - 1.51/day, September - 1.65 /day, October - 1.19 /day, and November - 1.25 /day. Surveys for owls occured at approximately weekly intervals. Daily averages were calculated relative to the number of days in those weeks in which the weekly period overlapped into the following month. The north and south sites had an equal number of collected owls until mid August. In mid August the number of owls collected in the south site increased sharply and continued at that rate through November (Figure 4). Hatching year owl collections comprised 70% of collected owls in the south site and 55% of collections in the north site after August 13.

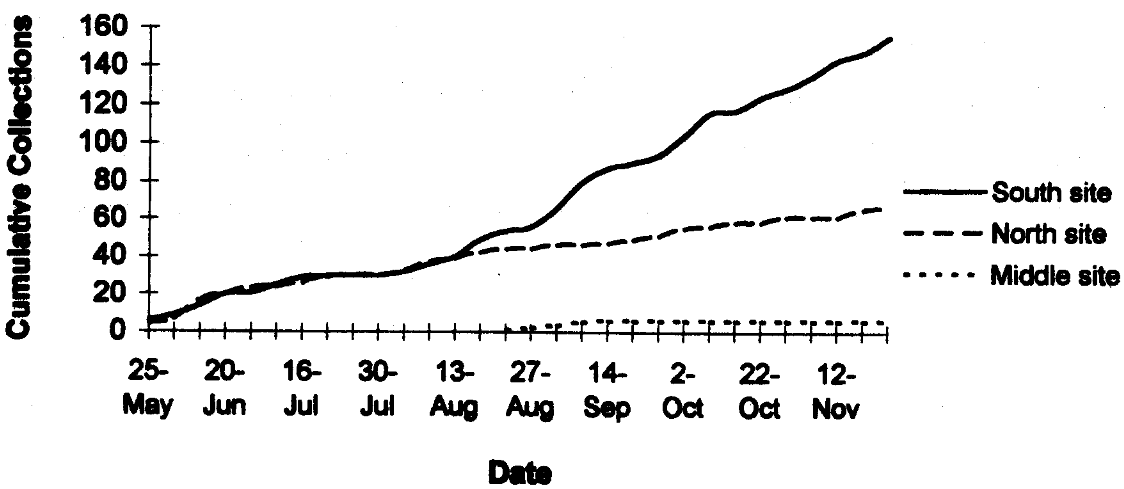

Figure 4. Cumulative collections of barn owls for all sites

Sex-ratio and Age Composition Seventy-four percent of the collected owls were female (Figure 5), which was significantly different from the expected 1:1 sex-ratio (Binomial Test; $z = 45.7$ $n = 137$, $p < 0.0001$). A significant age bias existed in the collected owls (Figure 6), with 61% of the owls identified as hatching year birds (Binomial Test; $z = 29.4$, $n = 176$, $p < .005$). There may be a greater number of hatching year owls collected due to proportionately more hatching year owls and / or, because they are at a greater risk of vehicular collision.

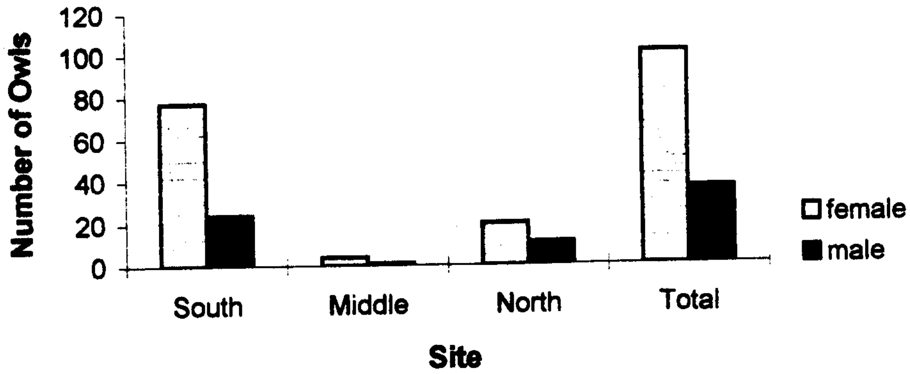

Figure 5. Composition of sex. Females were 77% of all collected barn

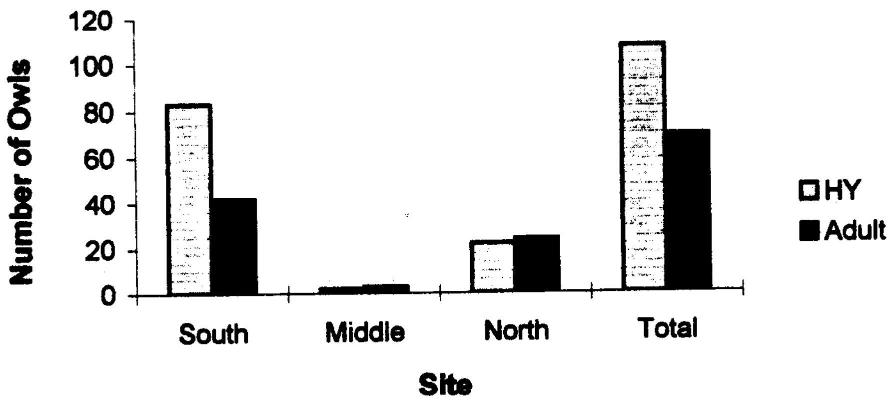

Figure 6. Age composition of collected barn owls.

<u>Traffic flow</u> The data on night time traffic flow available at this time were insufficient for an accurate analysis. Future traffic flow data taken from more monitoring stations, than obtained during this study should provide better estimates about traffic related mortality.

Life Table Model

We constructed a life table model (Appendix) using data from past life history studies done in the California central valley (Schulz and Yasuda 1985), southern California (Henny 1969) and Utah (Marti 1994) to predict the net reproductive rate (Gotelli 1995). When the net reproductive rate is: greater than one the population is increasing; equal to one the population is stable and lower than one the population is in decline. Based on data from Marti (1990), we assumed that an adult is reproductively active for eight years. In the absence of traffic related mortality our model gives Ro=1.86, so the population increases by about 86% per eight year active reproductive period. The results shown in Figure 7 represent the fraction of total mortality due to traffic for either adults (panel a) or hatching year individuals (panel b). That is, a value of 0.1 on the abcissa means that 10% of the total mortality was due to traffic. Thus, our results predict that when about 48% of adult mortality is due to traffic or 27% of hatching year mortality is due traffic, the population growth rate drops below one.

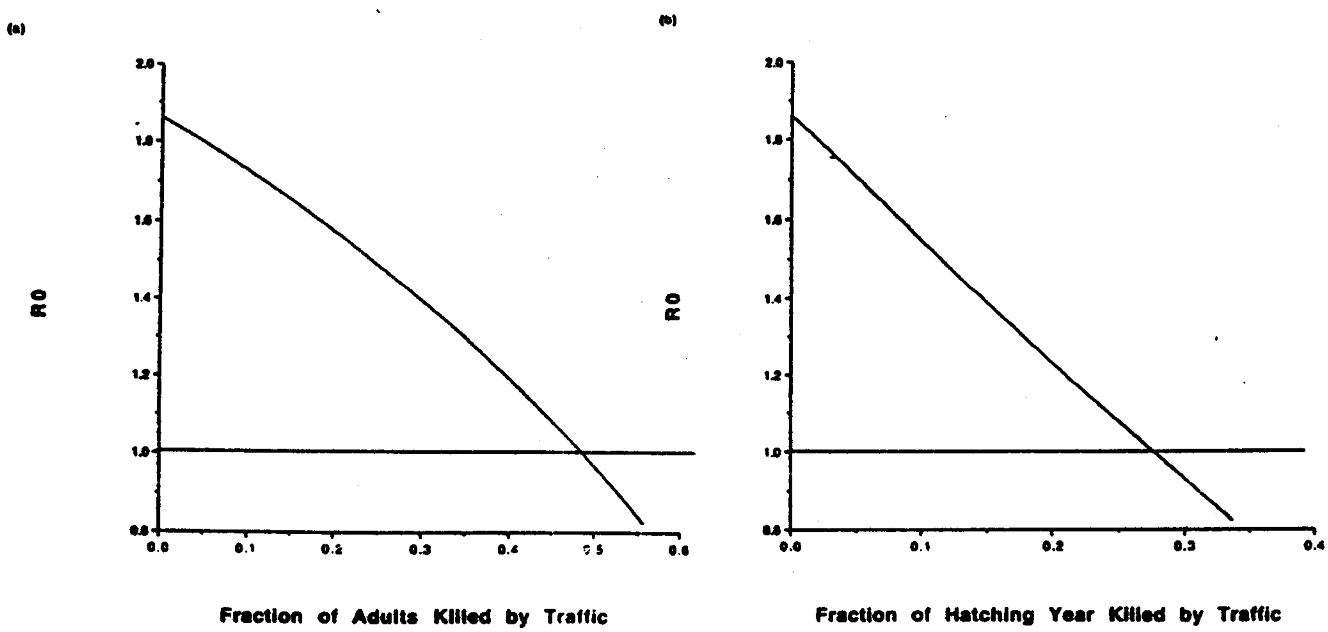

Figure 7. Predicted reproductive rate in the presence of traffic related moratlity.

Discussion

The number of owls collected during the 27 weeks of this study suggests a higher mortality of owls along roads than earlier studies conducted in the US and abroad. From 1980 to 1985 Schulz (1986) collected an average of 150 owls per year along roads of the California central valley. Although a large number of owls were collected, the total number of owls killed in this study may actually be far greater than those collected. Birds are not often immediately killed after vehicular collision and may fly off only to die a short distance away. Owls may have been overlooked in the roadside vegetation, undetected from a passing automobile and then removed by scavenging birds or mammals. Removal by scavengers and passing motorists may have substantially reduced total collections (pers observ).

The over-representation of collections in pasture/open habitat (Figure 3) strongly suggests the increased presence of barn owls in pasture/open lands compared to rotated crop land. This corroborates past studies that have found barn owl hunting preferences in grassy habitats (Bunn et al. 1982, Bloom 1979, Hume 1991, Colvin et al 1984, Marti 1988, Taylor 1994). The south site has three different wilderness preserves, one river and two large sloughs. This abundance of riparian habitat and extensive patches of irrigated pastures, provide long stretches of moist grasslands that make it the ideal barn owl habitat.

A total of 82 barn owl were collected along a 10.5km stretch (north-south) in the south site. The surrounding habitat along this stretch of freeway is comprised mostly of pasture, open habitat and small farms. The large number of nearby trees could provide for nesting and roost sites within close proximity to moist, grassy, flat terrain. Since foraging areas are not defended by barn owls, large numbers of owls may utilize areas rich in prey. Voles and shrews, the frequent prey of choice (Taylor 1994, Schulz pers comm.), are often found in such grassy habitat type. Colvin (1984) found most owls hunted within 2-3 km of the nest and Taylor (1994) observed that, from May through July, 89 % of the foraging occurred within 1 km of the nest. While collecting owls, voles were observed moving in the vegetation and found dead along side the highway.

Although no trapping was done to quantify rodent density, this stretch of habitat appeared to have all the characteristics of the preferred barn owl habitat and may have been a factor for the high number of collected barn owls.

In contrast to the south site, the north site was largely comprised of rotated crop land and may not provide a similar prey density. Schulz (1986) found a correlation with collected owls and increased agricultural activity. This may have been the cause of the collections in the north and middle sites. Other raptors were observed in large numbers, hunting over recently plowed fields, but were not present a few days later. Areas intensively cultivated may not provide the right habitat for barn owls (Bloom 1979). The study area incured mean high temperatures in excess of 92°F from July through September. Owls may not have been collected as frequently, in the rotated crop habitat, due to extensive dry periods when the fields lay plowed between crops. Soils, without water from irrigation would produce less vegetation cover and would result in lower prey density and then be hunted less frequently.

The sharp increase in collections in the south site from mid August through November also correlates with an increase in the percentage of collected hatching year owls. Although barn owls nest all year round, by late summer their would be the largest proportion of hatching year birds. Fewer owls were collected during June and July most probably due to the a reduced number of hatching year owls in the population. This high number of fatalities throughout the warmer months is in contrast to recoveries in Europe and the northern US. Most barn owl fatalities in those regions occur in the winter due to exposure to cold and starvation (Stewart 1952, Henny 1969, Glue 1973, Frylestam 1972, Bairlien 1985, Newton et al. 1991, Taylor 1994). The study will continue through winter to gain more information about annual mortality trends of the local owl populations.

One of the most surprising results was the skewed sex-ratio. Past studies of raptors have indicated sex-ratios of collected owls much closer to unity, in both Europe and the United States, especially in monogamous species (Newton 1979). In Great Britain 52 % of the 627 barn owls recovered were female (Newton et al. 1991). In Europe of the 418 barn owls 53 % were females (Mlikovsky and Piechocki 1984). In New Jersey, 65 % (n = 18) of the collected screech owls *Otus asio* were females, while the sex-ratio was even in the northern saw-wet owls *Aegolius acadicus* (Loos and Kerlinger 1993).

This imbalance in the number of collected female barn owls may be due to greater vulnerability to traffic collisions and /or the presence of more females in the local populations. Females may not be as capable as the males in avoiding collision with vehicles. Differences in reproductive strategies have lead to a reversed sexual dimorphism with the males having 82% the body mass of females in Utah (Marti 1990). The lighter body mass allows the males to hunt much more efficiently with greater maneuverability than the heavier females (Newton 1979). This may reduce the number of males dying from collisions with vehicles, even though the male does most of the hunting throughout the breeding season (Bunn et al. 1982) and are more exposed to highway traffic. There may be more females in the local population due to dispersal. Females are know to disperse twice the distance as the males and may be dispersing into the ideal habitat found in the south site.

As with the female-bias, the high collection percentage of hatching year owls may be related to the presence of more juveniles in the population, and / or their greater vulnerability. The results in this study are consistent with the age distribution of recovered barn owls in previous studies, although none have done so exclusively in relation to traffic mortality. First year owls comprised 61 % of recovered barn owls in California (Stewart 1952), 70 % of recoveries in Great Britain (Newton et al. 1991), and 71.8 % in Germany (Baerlein 1985). In Great Britain 39 % of all first year owls died as a result of collision on roads, rails or into wires (Glue 1971).

More hatching year owls may be collected due to a greater proportion of hatching year owls in the population. With more juveniles in the population there is a greater chance of more hatching year barn owls being killed in traffic collisions. The high proportion of hatching year owls collected coincides with the Great Britain study that showed a first year mortality peak in September (Glue 1973).

Unlike most other raptors, immature barn owls are equipped with all the morphological advantages of the adults (Marti 1990) but still may be more vulnerable than adults. They can hunt with the same slow quartering flight and then drop upon their prey, but hatching year owls may have some disadvantage due to inexperience (Marti 1990).

Learning may be involved in detecting prey and making choices from sounds emitted by rodents (Taylor 1994). Although well equipped to capture prey, few owls are allowed extra chances while learning to hunt in front of fast moving traffic.

The data on traffic flow was insufficient to assess the effects of traffic flow on barn owl mortality. Monitoring of night time traffic flow is only conducted from select stations for a few weeks at a time and did not provide enough data for a fair assessment. Ilner (1992) found in Europe that traffic speed, not traffic flow, was the major factor in traffic caused fatalities. Roads with a traffic speed greater than 80 km per hour had 21 times the number of traffic caused owl fatalities than roads with traffic speeds of less than 80 km per hour. Traffic flow will continue to be studied by these authors to assess the effect on mortality.

Traffic induced mortality of adults could have detrimental effects on local populations of barn owls. Estimates of barn owl mortality caused by traffic collisions rose from 6 % in 1910-54 and 15 % in 1955-69 (Glue 1971) to 42 % in 1963-89 (Newton et al. 1991). Mortality of banded and recovered barn owls estimated to be caused by traffic collisions ranges from 30 % (Ilner 1992) to 42 % (Newton et al. 1991). Mortality of owls caused by humans may be overestimated due to the probability of finding dead banded birds related to their geographical locations. Traffic related mortality is most noticeable and may contribute to higher estimates (Newton 1979). Ilner (1992), in a study on road deaths and effects on barn owl breeding populations in Europe, corrected estimates of adult traffic related mortality to 6.5 % of the total mortality.

In temperate climates, with cold winters, barn owl mortality is the highest during winter because of their narrow thermoneutral zone between 22.5-32.5 °C. In Scotland the population declined when the breeding adult annual mortality rate was greater than 35 % (Taylor 1994). In the central valley of California, with its milder climate, the main cause of mortality in the central valley appears to be traffic. Schulz (1986) found that 64 % of 25 recovered banded barn owls died as a result of vehicular collision.

The number of offspring produced, adult and juvenile owl mortality, the immigration rate and the number of potential breeding birds determine the net reproductive rate (Taylor 1994). The difficulty in predicting the population trends lies in the fact that little is know about the proportion of adults that are breeding and population densities of barn owls in much of California (Bloom 1979). The proportion of non-breeding females in Scotland ranged from 0-16 % as a result of low period in the vole cycle but there is no evidence of owl populations cycling with voles in the US (Taylor 1994).

The model was constructed to gain some insight about the effects of traffic related mortality on barn owl population growth. Without any traffic related mortality the population would be growing at about 86 % per eight year reproductive period. The model indicated that when about 48%of adult mortality or 27% of hatching year mortality was due to traffic the population growth rate drops below one and the population would be in decline. This takes place when about 15% of the population is killed by traffic. The demographics of local populations are needed to assess the mortality related to traffic. The model assumed no immigration of any owls.

Barn owls have a tremendous recovery capacity with improvements in prey availability, nest site availability and weather. If the reproductive rate drops below one the immigration of dispersing owls may help to maintain the population size. More studies are needed to assess the population density, number of breeding pairs and sex-ratio in the population. Traffic related mortality will continue to rise with construction of new roads and expansion of old roads that allow vehicles to travel at greater speeds. Restoration projects, like those in progress along Interstate 5 in the south site, may be increasing mortality of bird species. Future projects at greater distances from such busy interstate highways may reduce the number of traffic fatalities. Additional studies are needed to assess these changes in land use especially when construction plans involve expansion into open riparian habitats.

Conclusion

The high numbers of roadside fatalities support past claims (Schulz 1986) that traffic collisions are a significant cause of barn owl mortality in the central valley of California. A significantly greater number of owls were found along highways which passed through pasture/open land habitats. The highest proportion of owls were collected in areas where there was an abundance of riparian habitat within close proximity to the pasture /open habitats. Barn owls have long been associated with these habitat types and evidence supports these as the preferred habitats (Bloom 1979, Bunn et al. 1982, Colvin et al 1985, Marti 1988, Taylor 1994). The significantly larger number of females collected may be due to a greater vulnerability or a female-biased sex-ratio due to a unique reproductive strategy. While males have evolved to become smaller, efficient, more agile flyers in response to a reproductive strategy of providing food for the female and offspring (Marti 1990), females may not be as capable in avoiding vehicular collisions.

There was significant difference in the average number of owls collected by month with a peak in recoveries in August and September. The difference in temporal patterns between the three sites is most likely due to the ideal habitat available in the south site. The sharp increase in the number of collected owls in the south site, after mid August, was due to the large number of hatching year owls collected. The significantly greater number of hatching year owls collected could be due to increased proportion of hatching year birds, vulnerability of recently fledged owls or a combination of both factors. The model calculating the net reproductive rate estimated that the population growth was > 1 until 48% of adult mortality or 27% of hatching year mortality is due to traffic. At that point the net reproductive rate drops below one and the population declines. Increased expansion of roads and highways with fast moving vehicles does not appear to be a condition that will decrease. The results in this study suggests that expansion into open riparian habitats should proceed with caution and more monitoring programs may help reduce this mortality.

Appendix

In this Appendix, we provide details of the life table model analysis of the effects of auto-induced mortality. We assume no density dependence in either fecundity or survival and that all females attempt to breed. If l(a) and m(a) are survival to age(a) and reproduction at age (a) of a female, her lifetime reproduction of daughters is (Gotelli 1995)

$$R_o = \sum m(a)\, l(a) \qquad \text{(A.1)}$$

Fecundity at age a is determined by the chance of successful nesting (N(a)), the average clutch size (E), the hatching success rate (H), fledging success rate (F) and average number of clutches per female (C) according to

$$m(a) = .5(N(a) \times E \times H \times F)\, C \qquad (A.2)$$

The values of the parameters used in the model are: E = 6 (Schulz and Yasuda 1985), H = 0.72 (Schulz and Yasuda 1985), F = 0.73 (Schulz and Yasuda 1985), C = 1 (Schulz and Yasuda 1985); N(a) = 0.56 (Henny 1969). A 50-50 sex ratio is assumed.

In the absence of vehicle-induced mortality, survivorship to age 1 is 51% and in all subsequent years is 80%; (Henny 1969). We corrected for vehicle-related mortality by increasing survivorship by 6.5% (Ilner 1992). Thus, in the absence of vehicle-related mortality, l(1)=(.475)(1.065) =.51 and l(a)= l(.752)(1.065)(a-1) = l(.80)(a-1). When the level of vehicle-related mortality is v, the corresponding values are l(1)=.51(1-v) and l(a)= l(.80)(a-1)(1-v).

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