106686

ENTERED

LA-UR-09-05092

August 10, 2009

*Approved for public release; distribution is unlimited.*

***Title***

# SEX RATIO AND CONTAMINANT IMPACTS ON REPRODUCTION: ADAPTIVE AND ENVIRONMENTAL CONSTRAINTS

***Authors***

**Jeanne M. Fair[1*], Randall T. Ryti[2], Mark D. Jankowski[1], Steven L. Reneau[3]**

[1] Los Alamos National Laboratory, Biosecurity and Public Health, Mailstop M888, Los Alamos, NM 87545, 87545 505-667-5659, FAX 505-665-3886, jmfair@lanl.gov

[2] Neptune and Company, Inc. 1505 15th St # B, Los Alamos, NM 87544

[3] Los Alamos National Laboratory, Earth and Environmental Sciences Division, Los Alamos, NM 87545

Los Alamos
NATIONAL LABORATORY
Los Alamos, New Mexico 87545

31956

*An Affirmative Action/Equal Opportunity Employer*

*This report was prepared as an account of work sponsored by an agency of the United States Government. Neither The Regents of the University of California, the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by The Regents of the University of California, the United States Government, or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of The Regents of the University of California, the United States Government, or any agency thereof. The Los Alamos National Laboratory strongly supports a researcher's right to publish; therefore, the Laboratory as an institution does not endorse the viewpoint of a publication or guarantee its technical correctness.*

# SEX RATIO AND CONTAMINANT IMPACTS ON REPRODUCTION: ADAPTIVE AND ENVIRONMENTAL CONSTRAINTS

*For Environmental Research*

August 10 2009

**LA-UR-09-05092**

**Jeanne M. Fair[1*], Randall T. Ryti[2], Mark D. Jankowski[1], Steven L. Reneau[3]**

[1] Los Alamos National Laboratory, Biosecurity and Public Health, Mailstop M888, Los Alamos, NM 87545, 87545 505-667-5659, FAX 505-665-3886, jmfair@lanl.gov

[2] Neptune and Company, Inc. 1505 15th St # B, Los Alamos, NM 87544

[3] Los Alamos National Laboratory, Earth and Environmental Sciences Division, Los Alamos, NM 87545

[*] Corresponding author

## 1. Introduction.

Variation in the offspring sex ratio in birds and small mammals in has been of great interest for a long time (Mayr, 1939) describing non-random sex allocation in relation to parental, ecological, and environmental factors. The numerous factors that have been to be associated with deviations from 50:50 sex ratio in offspring and populations include sex differences in dispersal activities (Gowaty, 1993), differences in helping behaviors between males and females (Emlen et al., 1986), food availability (Myers, 1978), and differences in reproductive strategies in males and females (Clutton-Brock, 1986; Daan and Buker, 1990; Siegel, 1978). Recent studies on sex ratio have focused on better explaining skewed sex ratios observed in nature (Nicolaus et al., 2009; Saino et al., 2008; van Dijk et al., 2008) such as impacts from hybridization (Neville et al., 2008) and climate (Darolova et al., 2009).

In addition to the adaptive or naturally-caused deviations in sex ratio, there has been increasing concern over the potential of anthropogenic contaminants in the environment to also cause sex ratio variation in wildlife. While many of these contaminants have been around for decades, more concern for the impacts from what (Wong, 2006) defines as *emerging contaminants* which are chemicals (including veterinary and human pharmaceuticals) that currently are being used and released into the environment and are of special concern due to widespread occurrence. Polychlorinated biphenyls (PCBs) are a class of chemically stable compounds that were produced for industrial and consumer products in the United States from the 1920's until 1977 and have also be shown to alter sex ratios (Norman et al., 2007; Vajda et al., 2008; Vega-Lopez et al., 2008). Each individual PCB congener represents one configuration of 209

that are possible, based on the number and location of attached chlorine atoms. These compounds bioaccumulate up the food chain and have also been implicated in potential to caused skewed sex ratios. Additionally, the different congeners of DDE and DDT have been found to impact sex allocation. The 2,49 congener of DDT binds to the estrogen receptor and elicits estrogen-like effects (Kupfer and Bulger, 1976).

For every study that provides evidence for the ecological impacts on non-random sex allocation, there are similar studies reporting no significant relationships of selected factors on sex ratio, even in the different populations of the same species (Rosivall et al., 2004). However, despite population differences in sex allocation impacted by myriad factors, it is important to investigate both offspring and adult sex ratios in wildlife in respect to potential environmental determinants and now contaminants of concern for altering sex ratio. Equally important, is to investigate sex ratios over several years and environmental conditions. If the understanding the impacts of contaminants on the sex ratios of wild populations is the goal, then environmental determinants and adaptive strategies must be considered simultaneously.

The adult sex ratio is a key parameter of the demography of animal populations, yet the causes of variation in adult sex ratio remain poorly understood. A prevalent hypothesis is that Adult sex ratio is regulated by intrasexual competition, which would cause more mortality or emigration in the sex of increasing frequency.

In the present study, we analyze two long-term data sets on the proportion of males to females. The first concern with offspring or brood sex ratio of a cavity-nesting bird species, the western bluebird (*Sialia mexicana*), and the second is the proportion of

males to female free ranging juvenile and adult rodents captured at the same location within the same years.

Compared to a similar analysis of nestling sex ratio variation in western bluebirds that found usually even sex ratios across years (Koenig and Dickinson, 1996), the western bluebirds in this study exhibited a wide range of0-100% females per nest. During the 12 breeding seasons of study from 1997 to 2008, the following environmental changes occurred at our location in New Mexico: a significant drought (Fair and Whitaker, 2008), a resulting wildfire of approximately 48,000 acres (Kokaly et al., 2007), and a large scale die-off of 90% of the pine trees (Breshears et al., 2005). Our study sites were chosen to estimate the impacts of a mix of potential contaminants on wildlife at our location and are both in potentially contaminated and non-contaminated locations. We sought to first study the relationships with endpoints such as clutch size and laying date or capture. Then, we analyzed the association with environmental factors including average maximum temperature and total precipitation. Lastly, we looked at location differences in sex ratio in respect to potential contamination and fire and habitat changes. A past analysis of western bluebird sex ratio of the first three years of this study was completed and there while the percent of females ranges from 0 to 100%, there were no relationships found with contaminated sites, locations, or years (Fair and Myers, 2002). This was primarily due to small sample sizes where more than 10 years of data may be required to adequately test for the determinants of sex ratio for this study.

Focusing on one avian species offspring sex ratio and total population sex ratio of several small mammal species with sex ratio data published at other locations (Havelka and Millar, 1997; Koenig and Dickinson, 1996; Myers et al., 1985), our objective is to

describe sex ratio variation in regards to environmental, life history, and possible toxiciologcal parameters for a location at northern New Mexico.

## 2. Methods and materials

### *2.1 Study Area*

This study was conducted on Los Alamos National Laboratory (LANL) land that is located in north–central New Mexico. The 106 $km^2$ Laboratory is situated on the Pajarito Plateau and consists of a series of relatively narrow mesas separated by deep, steep-sided canyons that decline east-southeast from the Jemez Mountains down to the Rio Grande River and nestboxes are located both in the canyons and the mesas. Six major vegetation community types are found in Los Alamos County: subalpine grassland, spruce–fir forest, mixed conifer forest, ponderosa pine forest, piñon–juniper woodland, and juniper grasslands (Foxx and Tierney 1985). During the winter of 1997, 450 bluebird boxes were placed on LANL in both contaminated and uncontaminated areas and boxes were added over the years resulting in 877 boxes. Nest boxes were placed approximately two meters off the ground on trees and spaced approximately 50-75 meters apart and span an elevational gradient of 6202 to 7563 feet.

### *2.2 Western bluebirds*

The western bluebird is widely distributed, sexually dichromatic, and monogamous species that nests in secondary nest cavities, insectivorous during the breeding season, and the nestlings are sexually dichromatic (Guinan et al., 2008). Starting in May 1997, nest boxes were visited and nests with eggs were considered active and visited weekly until the first eggs hatched (day = 0) and then the nestlings fledged. Hatch date, clutch size, and hatching and fledging success was recorded for each nest.

Data were collected for the summer breeding seasons of 1997 through 2008. Nestlings and adults were captured at each nest box and banded with USFWS aluminum bands, with the nestlings banded between age 10 and 16 days old. The sex was determined by plumage color identification of nestlings that were 15 days or older. Morphological measurements were taken all adults, but not all nestlings as they were banded on different ages. Once eggs hatched, adults were captured either by mistnet in front of the nest box or a wood door placed on the front of the box and pulled once the adult entered the box.

***2.4 Data Analysis***

For this analysis only nests with clutch sizes larger than three and all nestlings were able to be sexed, usually after day 15 of age. In addition, only the first clutches of nests were used and only nests with no helpers. The sex for the bluebirds was scored as 0 = female or 1 = male. We examined relationships of sex ratios in with the year (YEAR), maximum mean temperature for the year (MAX), total annual precipitation (PRECIP), elevation (ELEV), and groups of locations for the capture site using logistic regression (Allison, 2001; Zhao and Chen, 2001). The Statistical Analysis System (SAS, 1987) was used for all statistical analyses. The selected explanatory variables (covariates) and the location as a random factor were modeled simultaneously using logistic regression in generalized linear mixed models (PROC GLIMMIX in SAS 8.2) allowing the analysis of the binomial error variance (Krackow and Tkadlec, 2001). We used an approach where we developed a list of factors that we thought might influence the sex ratio of the offspring or adults (Burnham and Anderson, 2002). From these factors we used a hierarchical modeling approach to arrive at a set of models ranked by second order Akaike's Information Criterion (AIC) values (Akaike, 1973; Link and Barker, 2006;

Yanagihara et al., 2003). We used AIC adjusted for small sample sizes (AICc), to determine which of the models, or combination (Burnham and Anderson, 2002).

## 3. Results

### *3.1 Western bluebirds*

A total of 302 nests were included in this analysis from a total of 2133 potential western bluebirds nests. Percentage females varied from 0 to 100% in all years across the whole study area. The ratio of the sexes did not vary from unity for any of the locational or environmental variables measured. Environmental variables that included elevation and hatch date supported the data better than any of the location variables that included watershed, canyon, and specific location (Table 1), however, these were also not significant (elevation, $F_{1,1211} = 1.35$, $P = 0.25$, hatch date , $F_{1,1211} = 0.13$, $P = 0.51$). There was no evidence that watersheds or years differed in the sex ratio of broods (Figure 2).

## 4. Discussion

There are few, to no studies documenting a skewed sex ratio of nests in birds related to potential exposure to contaminants (Fry and Toone, 1981). Fry and Toone (1981) found feminization of gull embryos injected DDT levels into eggs that were of the same magnitude as those found in seabird eggs in southern California in the late 1960's and early 1970's. Sex-ratio skew in breeding populations of birds in polluted areas has been postulated to be the result of selective mortality of males (Hunt et al., 1980; Nisbet and Drury, 1984; Shugart, 1980). Although no evidence that male birds are more sensitive to pollutants has been demonstrated, it is known that female birds are able to excrete organochlorines and other contaminants into the egg and the nestlings are able

to more rapidly eliminate the contaminants than adults (Fair and McEwen, 1994). In addition, an alteration in the sex ratio of the population could be achieved by differential survival of females in addition to the exclusion of developmentally feminized males from the breeding population (Fry et al., 1987).

In this study we documented no differences in the sex ratio of broods of western bluebirds in relation to locations that may potentially contain a mixture of various types of contaminants. Due to the observed wide variation in brood sex ratio of 0 to 100% females, this study sought to try and explain this variation due to concern for exposure to potential endocrine disrupting contaminants and other possible environmental variables known to cause skewed brood sex ratios (Badyaev et al., 2003; Saino et al., 2008).

However, there has also been evidence in other species such as the Eurasian treescreeper (*Certhia familiaris*) that male nestlings are more costly to produce since they have higher mortality and are larger in size, suggesting an association with habitat quality with sex allocation (Suorsa et al., 2003). Because sons and daughters can differ in reproductive value and costs, the sex of the offspring can be related to the tradeoff between life history traits (Trivers and Willard, 1973). Trivers and Willard (1973) proposed that whenever there is sexual selection among males, natural selection should favor mothers that produce sons when in good condition and daughters when in poor condition. The 12 years of this study included a severe drought from 2001-2003 that impacted nestling mortality and immune function of the western bluebird nestlings (Fair and Whitaker, 2008). Western bluebirds are a socially monogamous dichromatic species (Guinan et al., 2008) and like the mountain bluebird (*Sialia currucoides*), extra-pair paternity may be enough to support sexual selection (Balenger et al., 2009).

There are five main hypotheses that provide adaptive explanations for sex ratio patterns in birds and mammals (Cockburn et al., 2002; Koenig and Dickinson, 1996). In a similar analysis of nestling sex ratio variation in western bluebirds, Koenig and Dickenson (1996) tested the five hypotheses for adaptive sex ratio variation. Koenig and Dickenson (1996) found no relationships found for brood reduction, breeder female age, presence of helper males, first-egg date, condition of the breeder female, or annual differences in environmental conditions. While compared to the above study, this study showed an overall higher amount of variation of 0-100% females per western bluebird nests. We did not use nest with male helpers in this analysis as although Koenig and Dickenson (1996) did not show an impact of helpers on nestling sex ratios, it could still add variation to the study if males helpers bias the sex ratio towards the helper sex (Emlen et al., 1986). While we did not measure adult female condition specifically, the drought years of 2001-2003 would have provided a possible test of female condition due to the strong impacts on the birds of an extreme drought. In addition, these years would have provided a test for nestling size dimorphism due the observed reduction in mass and survival of the nestling western bluebirds (Fair and Whitaker, 2008). The western bluebirds this study a similar female biased or dispersal but still lower overall than reported by Koenig and Dickenson (1996) (6% unpublished data). While female bias dispersal is predicted to lead to a female bias offspring sex ratio, 94% of the birds that are hatched on our study area either do not return to their natal area or survival is impacted post fledgling. Since werstern bluebirds are bias for female dispersal, looking at hatch date and offspring sex ratio, we could test the hypothesis that sex ratio should be bias

more towards early in the season and shifting towards females later in the season. We found no evidence that hatch date was related to offspring sex ratio.

For the western bluebirds, it is possible that all five adaptive hypotheses could be simultaneously working, making it difficult to disentangle sex ratio bias attributed to one strategy. However, for anthropogenic causes of possible contaminant exposure, it should be less muddled for location differences between areas of concern for contaminants and references sites. We found no differences in locations for offspring sex ratios, so we fail to reject the null hypothesis that locations with possible environmental contaminants at Los Alamos National Laboratory are attributed to a bias in offspring sex ratio in western bluebirds.

**Acknowledgments**

We thank the following people for excellence in the field: K. Burnett, K. Colestock, J. Foxx, C. Hathcock, D. Keller, L. Maestas, E. Powell, R. Robinson, S. Sherwood, S. Whitaker. We are grateful to Orrin Myers for establishing the avian nest box monitoring network. We thank Hector Hinojosa for comments on an earlier manuscript draft. This research was funded by the Environmental Restoration Program through Los Alamos National Security, LLC, operator of the Los Alamos National Laboratory under Contract No. DE-AC52-06NA25396 with the U.S. Department of Energy.

**References**

Akaike, H., Information theory and an extension of the maximum likelihood principle. In: B. N. Petran, F. Caski, Eds.), International symposium on information theory, Budapest, Hungary, 1973, pp. 267-281.

Allison, P. D., 2001. Logistic Regression Using the SAS system: Theory and Application. SAS Publishing, Cary, NC.

Badyaev, A. V., et al., 2003. Interaction between maternal effects: Onset of incubation and offspring sex in two populations of a passerine bird. Oecologia. 135**,** 386-390.

Balenger, S. L., et al., 2009. Extra-pair paternity in the socially monogamous mountain bluebird *Sialia currucoides* and its effect on the potential for sexual selection. Journal of Avian Biology. 40**,** 173-180.

Breshears, D. D., et al., 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings of the National Academy of Sciences of the United States of America. 102**,** 15144-15148.

Burnham, K. P., Anderson, D. R., 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Springer, New York, NY.

Clutton-Brock, T. H., 1986. Sex ratio variation in birds. Ibis. 128**,** 317-329.

Cockburn, A., et al., Sex ratios in birds and mammals: can the hypotheses be disentangled? In: I. C. W. Hardy, (Ed.), Sex Ratios. Concepts and Research Methods. Cambridge University Press, Cambridge, UK, 2002, pp. 424.

Daan, S., Buker, J. B., 1990. Adaptive seasonal variation in the sex ratio of kestrel broods. Functional Ecology. 4**,** 143-148.

Darolova, A., et al., 2009. Extreme brood sex ratios in Bearded Tits, *Panurus biarmicus.* Ibis. 151**,** 191-195.

Emlen, S. T., et al., 1986. Sex-ratio selection in species with helpers at the nest. . American Naturalist. 127**,** 1-8.

Fair, J. M., McEwen, L. C., 1994. Organochlorine residues in nesting killdeer, *Charadrius vociferus*, and their eggs in North Dakota. Canadian Field-Naturalist. 108**,** 328-331.

Fair, J. M., Myers, O. B., 2002. Early reproductive success of western bluebirds and ash-throated flycatchers: A landscape-contaminant perspective. Environmental Pollution. 118**,** 321-330.

Fair, J. M., Whitaker, S. J., 2008. Avian cell-mediated immune response to drought. . Wilson Journal of Ornithology. 120**,** 813-819.

Fry, D. M., Toone, C. K., 1981. DDT-induced feminization of gull embryos. Science. 213**,** 922-924.

Fry, M. D., et al., 1987. Sex ratio skew and breeding patterns of gulls: demographic and toxicological considerations. Studies in Avian Biology. 10**,** 26-43.

Gowaty, P. A., 1993. Differential dispersal, local resource competition, and sex ratio variation in birds. American Naturalist. 141**,** 263-280.

Guinan, J. A., et al., Western Bluebird (*Sialia mexicana*). In: A. Poole, (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, 2008.

Havelka, M. A., Millar, J. S., 1997. Sex ratio of offspring in Peromyscus maniculatus borealis. Journal of mammalogy 78**,** 626-637.

Hunt, G. L., et al., 1980. Sex ratio of wetern gulls, *Larus occidentalis* on Santa Barbara Island, California, USA Auk. 97**,** 473-479.

Koenig, W. D., Dickinson, J. L., 1996. Nestling sex-ratio variation in western bluebirds. Auk. 113**,** 902-910.

Kokaly, R. F., et al., 2007. Characterization of post-fire surface cover, soils, and burn severity at the Cerro Grande Fire, New Mexico, using hyperspectral and multispectral remote sensing. Remote Sensing of Environment. 106**,** 305-325.

Krackow, S., Tkadlec, E., 2001. Analysis of brood sex ratios: Implications of offspring clustering. Behavioral Ecology and Sociobiology. 50**,** 293-301.

Kupfer, D., Bulger, W. H., 1976. Studies on mechanism of estrogenic actions of O,P DDT Interaction with estrogen receptor. . Pesticide Biolchemistry and Physiology. 6**,** 561-570.

Link, W. A., Barker, R. J., 2006. Model weights and the foundations of multimodel inference. Ecology. 87**,** 2626-2635.

Mayr, E., 1939. The sex ratio in wild birds. American Naturalist. 73**,** 156-179.

Myers, J. A., 1978. Sex ratio adjustment under food stress maimization of quality or numbers of offspring. . American Naturalist. 112**,** 381-388.

Myers, P., et al., 1985. Ambient-temperature and rainfall. An effect on sex ratio and litter size in deer mice. A. Journal of Mammalogy. 66**,** 289-298.

Neville, K. J., et al., 2008. Nestling sex ratio of golden-winged warblers Vermivora chrysoptera in an introgressed population. Journal of Avian Biology 39**,** 599-604.

Nicolaus, M., et al., 2009. Sex-specific effects of altered competition on nestling growth and survival: an experimental manipulation of brood size and sex ratio. Journal of Animal Ecology. 78**,** 414-426.

Nisbet, I. C. T., Drury, W. H., 1984. Supernormal clutches in herring gulls, *Larus argentatus* in New England, USA Condor. 86**,** 87-89.

Norman, A., et al., 2007. Studies of uptake, elimination, and late effects in atlantic salmon (Salmo salar) dietary exposed to di-2-ethylhexyl phthalate (DEHP) during early life. Archives of Environmental Contamination and Toxicology. 52**,** 235-242.

Rosivall, B., et al., 2004. Brood sex ratio adjustment in collared flycatchers (Ficedula albicollis): results differ between populations. Behavioral Ecology and Sociobiology. 56**,** 346-351.

Saino, N., et al., 2008. Ecological and phenological covariates of offspring sex ratio in barn swallows. Evolutionary Ecology. 22**,** 659-674.

SAS, I., 1987. SAS/STAT guide for personal computers. SAS Institute, Inc., Cary, NC.

Shugart, G. W., 1980. Frequency and distribution of polygyny in great lakes herring gulls, *Larus argentatus* in 1978. Condor. 82**,** 426-429.

Siegel, H. S., 1978. Effect of age and sex on the associated constant and binding capacity of chicken serum for corticosteroid. . Poultry Science. 57**,** 778-784.

Suorsa, P., et al., 2003. Forest management is associated with physiological stress in an old-growth forest passerine. Proceedings of the Royal Society Biological Sciences Series B. 270**,** 963-969.

Trivers, R. L., Willard, D. E., 1973. Natural selection of parental ability to vary the sex ratio of offspring. Science. 179**,** 90-92.

Vajda, A. M., et al., 2008. Reproductive disruption in fish downstream from an Estrogenic wastewater effluent. Environmental Science & Technology. 42**,** 3407-3414.

van Dijk, R. E., et al., 2008. Offspring sex ratio in the sequentially polygamous Penduline Tit *Remiz pendulinus.* Journal of Ornithology. 149**,** 521-527.

Vega-Lopez, A., et al., 2008. Estrogenic effects of polychlorinated biphenyls and relation to cytochrome P4501A activity in the endangered goodeid fish *Ameca splendens.* Environmental Toxicology and Chemistry. 27**,** 963-969.

Wong, C. S., 2006. Environmental fate processes and biochemical transformations of chiral emerging organic pollutants. Analytical and Bioanalytical Chemistry. 386**,** 544-558.

Yanagihara, H., et al., 2003. Bias correction of AIC in logistic regression models. Journal of Statistical Planning and Inference. 115**,** 349-360.

Zhao, L., Chen, Y., 2001. Comparison of logistic regression and linear regression in modeling percentage data. Applied and Environmental Microbiology. 67**,** 2129-2135.

Table 1. AIC model selection results for bluebird offspring sex ratios.

| Model | K | AICc | AICc Difference | wi |
|---|---|---|---|---|
| Global | 25 | 1708.02 | 24.03 | 0.00 |
| Elevation hatch | 3 | 1683.99 | 0.00 | 0.87 |
| Elevation hatch temp precip | 4 | 1687.85 | 3.86 | 0.13 |
| Temp precip | 3 | 1707.15 | 23.16 | 0.00 |
| Watershed | 12 | 1715.19 | 31.20 | 0.00 |
| Year watershed | 23 | 1723.95 | 39.96 | 0.00 |
| Location | 29 | 1726.10 | 42.11 | 0.00 |
| Watershed canyon location | 31 | 1730.19 | 46.20 | 0.00 |

Hatch = ordinal hatch date, temp = average maximum annual temperature, precip = total annual precipitation (mm).

Figure 1. Los Alamos National Laboratory watersheds used in the study.

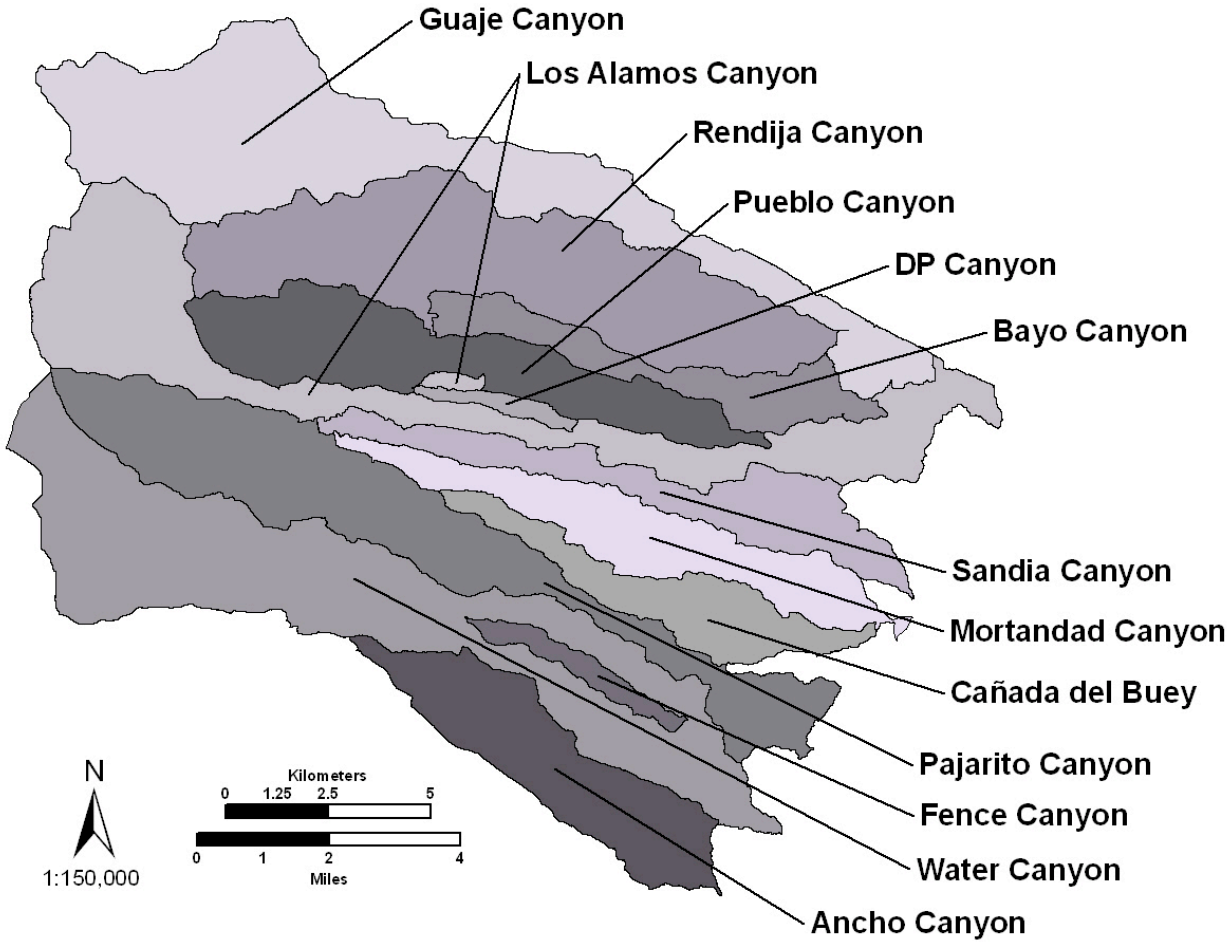
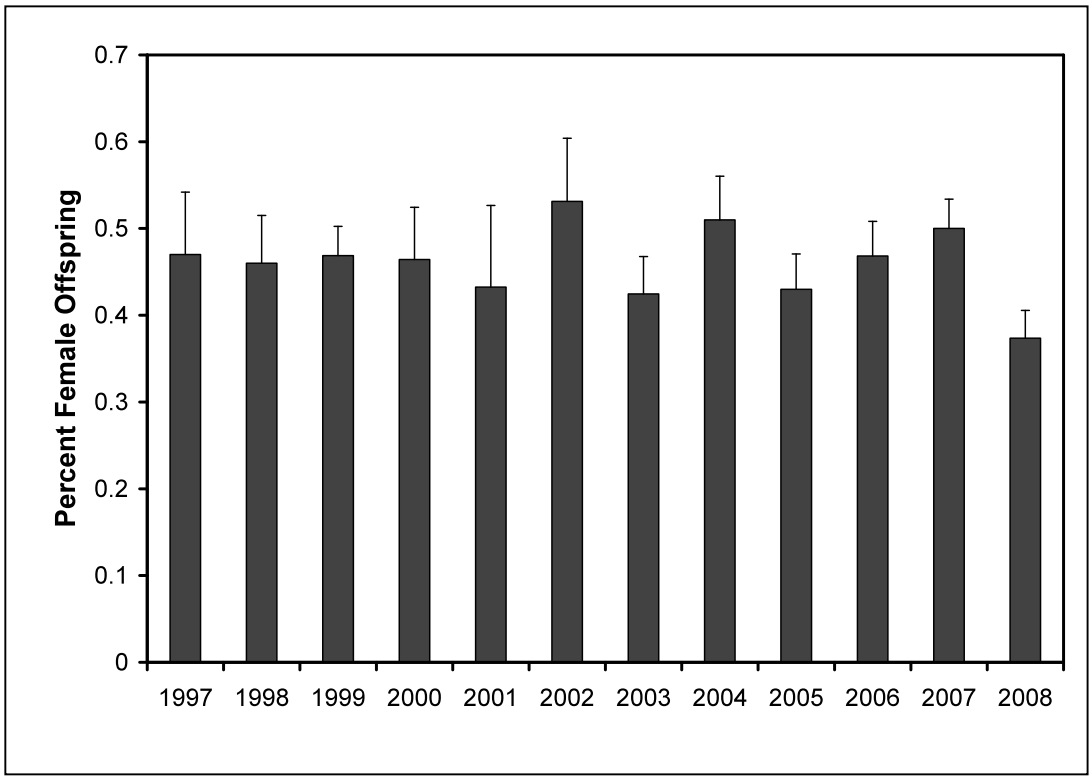
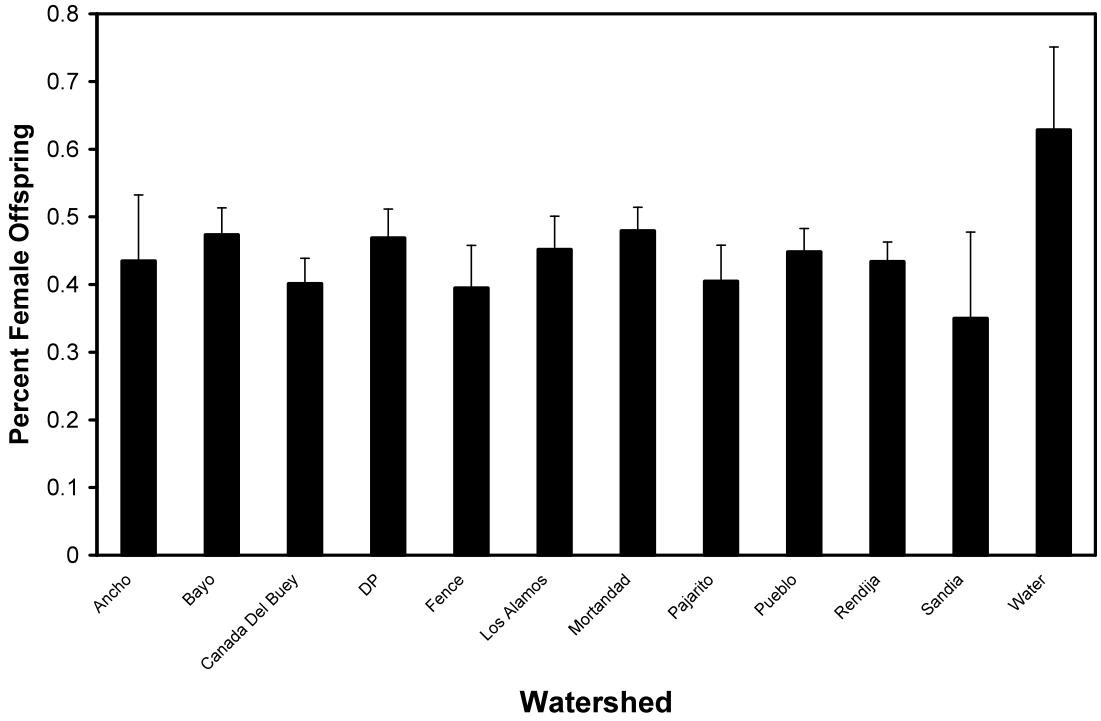

Guaje Canyon
Los Alamos Canyon
Rendija Canyon
Pueblo Canyon
DP Canyon
Bayo Canyon
Sandia Canyon
Mortandad Canyon
Cañada del Buey
Pajarito Canyon
Fence Canyon
Water Canyon
Ancho Canyon
N
1:150,000
Kilometers
0 1.25 2.5 5
0 1 2 4
Miles

Figure 2. Average percent female bluebird offspring from 1997 through 2008 (+S.E.) and average percent female by watershed.


Percent Female Offspring
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


Percent Female Offspring
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Ancho
Bayo
Canada Del Buey
DP
Fence
Los Alamos
Mortandad
Pajarito
Pueblo
Rendija
Sandia
Water
Watershed