RECOVERY OF THE BLUNT-NOSED LEOPARD LIZARD: PAST EFFORTS, PRESENT KNOWLEDGE, AND FUTURE OPPORTUNITIES

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Abstract: The blunt-nosed leopard lizard (*Gambelia sila*) has been listed as endangered since 1967. Notable efforts on the systematics and ecology of this species were done in the 1960's and 1970's, particularly by R. Montanucci and K. Tollestrup. Currently, we are finishing a 4-year study on a foothill population of this species. The data derived from these research efforts are only the beginning of what is necessary for recovering this species. More data are needed about life histories, population dynamics, genetics, response of populations to grazing and pesticides, and a variety of other basic questions if we are serious about conservation. We present recommendations about what research is necessary for obtaining data for recovering the blunt-nosed leopard lizard, and give the methodology needed for conducting this research.

The blunt-nosed leopard lizard (*Gambelia sila*) is a relatively large, predatory reptile of arid habitats in the San Joaquin Valley and adjacent valleys of California (see Jennings 1987, Frost and Collins 1988, and Collins 1990 for the use of *sila*). This species is listed as an endangered species by the state of California and the federal government due, in part, to degradation and loss of habitat (Montanucci 1965, U.S. Fish and Wildlife Service 1980). The blunt-nosed leopard lizard was listed as endangered in 1967, which reflects the severity of habitat loss. Based on an inspection of Fig. 1, the blunt-nosed leopard lizard has probably lost 80-85% of its native range. A recovery plan was approved for this species (U.S. Fish and Wildlife Service 1980) and a second draft plan was circulated (U.S. Fish and Wildlife Service 1985).

Loss of habitat for blunt-nosed leopard lizards and other species on the floor of the San Joaquin Valley has been the result of cultivated agriculture, oil development, and urban expansion. Besides direct loss of habitat, remaining lands that support blunt-nosed leopard lizards are grazed by livestock, and overgrazing of vegetation often has been cited as detrimental to populations of vertebrates inhabiting arid regions (Bury and Busack 1974, Jones 1981, Grant et al. 1982, Bock et al. 1984). Spraying of insecticides also has occurred on blunt-nosed leopard lizard habitat for many decades, and the direct and indirect effects of pesticide application on this species are unknown, but spraying is suspected to be harmful, either by direct lizard mortality or a reduction in abundance of arthropod prey (U.S. Fish and Wildlife Service 1985).

PAST EFFORTS

Results of several long-term studies on the blunt-nosed leopard lizards have been published in peer-reviewed journals since 1965 (Table 1). Other published works deal with this species as it relates to other crotaphytiforms (Table 1). Richard Montanucci wrote the first comprehensive papers on the ecology of the blunt-nosed leopard lizard (Montanucci 1965, 1967, 1970). These papers were followed by works on systematics and morphology, including the recognition of *Gambelia* separate from *Crotaphytus*, and *silus* (*sila*) as a full species (Montanucci 1969, 1970, 1978; Montanucci et al. 1975). The above changes in taxonomy for the blunt-nosed leopard lizard have not been accepted by everyone (Tanner and Banta 1977). Kristine Tollestrup compared the ecology, behavior, social structure, and reproductive parameters between *Gambelia sila* and *Gambelia wislizenii* (Tollestrup 1982, 1983). A short-term study of the structure of a valley floor population of blunt-nosed leopard lizards occurred at Pixley National Wildlife Refuge (NWR; Uptain et al. 1993).

Many unpublished works have been written about the blunt-nosed leopard lizard since 1975 (Table 2), including a recovery plan by the U.S. Fish and Wildlife Service (1980). Most studies have dealt with determining the effects of oil and gas development on this species and environmental factors correlated with species presence. These studies were of short duration and have not contributed greatly to data on life-history parameters needed for modeling population viability. They do, however, give some estimate of current distribution and of the ability of blunt-nosed leopard lizards to tolerate disturbance.

PRESENT KNOWLEDGE

We have completed four years of study of a foothill population of blunt-nosed leopard lizards on the Elkhorn Plain in San Luis Obispo County (Williams et al. 1992). The objective was to determine the effect of grazing of

Table 1. Published studies of *Gambelia sila.*

Ecology:	Montanucci 1965, 1967; Tollestrup 1982.
Food Habits:	Montanucci 1965, 1967.
Growth:	Tollestrup 1982.
Morphology:	Montanucci 1965, 1967, 1969, 1970, 1978.
Reproduction:	Montanucci 1965, 1967; Tollestrup 1982.
Behavior and Activity:	Montanucci 1965, 1967; Tollestrup 1982, 1983.
Demography:	Tollestrup 1982; Uptain et al. 1993.
Taxonomy:	Weiner and Smith 1965; Montanucci 1969, 1970, 1978; Montanucci et al. 1975; Tanner and Banta 1977.

Table 2. Unpublished studies of *Gambelia sila*[1].

Ecology and Behavior:	Tollestrup 1979a; Murphy 1980; Williams et al. 1992.
Food Habits:	Kato et al. 1987a.
Reproduction:	Tollestrup 1979a; Williams and Germano 1991; Williams et al. 1992.
Demography:	Uptain et al. 1985; Williams and Germano 1991; Williams et al. 1992.
Distribution:	Barclay et al. 1975; Tollestrup 1979b; Jones 1980; Chesemore 1981; O'Farrell et al. 1981; Kato et al. 1987b.; Williams 1990.
Habitat Requirements:	Murphy 1980; O'Farrell et al. 1981; Kato et al. 1987b.
Impact Assessment:	Madrone Associates 1979; Chesemore 1980; Mullen 1981; O'Farrell and Kato 1980; O'Farrell and Sauls 1982a, 1982b; Kato and O'Farrell 1986; Williams and Germano 1991; Williams et al. 1992.
Censusing Methods:	Tollestrup 1976.
Population Viability Modeling:	Buechner 1989.

[1] This does not include bibliographic summaries, general biological assessments, or agency opinion documents.

livestock on a population of blunt-nosed leopard lizards, but dry climatic conditions since 1989 have kept cattle off the range. We had an opportunity, however, to assess demographic changes during this drought period (Germano et al., unpub. data). The general ecology of blunt-nosed leopard lizards has been described for valley floor populations by Montanucci (1965, 1967) and Tollestrup (1982, 1983). We have combined this understanding with information from the foothill population on the Elkhorn Plain to summarize (without specific citations in most instances) the general ecology of blunt-nosed leopard lizards.

Blunt-nosed leopard lizards occur in dry-land habitats of the San Joaquin Valley, Carrizo Plain, Elkhorn Plain, and southeastern Cuyama Valley (Fig. 1). They once may have occurred as far north as San Joaquin County (Montanucci 1965), and are still found in grassland habitat in western Madera County (Williams 1990). They can be found in *Atriplex* scrub, *Ephedra* scrub, alkali sink, non-native grassland, and washes. Areas that are permanently wet or that have dense growth of shrubs do not support populations of blunt-nosed leopard lizards (Montanucci 1965). Washes have been considered by some to be prime habitat, but this may be true only in areas where washes traverse otherwise unsuitable habitat. We have not found washes to be of particular importance to blunt-nosed leopard lizards on the Elkhorn Plain. Blunt-nosed leopard lizards generally are found in areas sparsely covered by herbaceous ground cover. However, density of herbaceous ground cover can change each year, and blunt-nosed leopard lizards appear to adjust their mode of predator avoidance to the density of cover (Germano et al., unpub. data). Populations of blunt-nosed leopard lizards occur from about 30 m to 750 m above sea level, but do not appear to use slopes > 30-40 degrees.

Adult male blunt-nosed leopard lizards are larger, on average, than adult females, have more massive heads, and have enlarged post-anal scales and femoral pores. In addition, adults differ in coloration during the breeding season: males have a general wash of salmon coloration over most of the body, and females have rusty red-colored patches laterally extending from the head to the rear legs. Males in some valley floor populations may not develop this salmon coloring (Montanucci 1965). In other respects, the sexes are similar. Adults vary in size from about 90 mm snout-vent length (SVL) to a maximum of 130 mm SVL. The only estimate of size at maturity was for valley floor populations, where females were reproductive at 86-90 mm SVL and males matured at 87 mm, based on the acquisition of breeding colors (Tollestrup 1982).

Adult male blunt-nosed leopard lizards are territorial, and first reproduction by young males may be related to becoming large enough to hold a territory (Tollestrup 1982, 1983). Generally, adults can be active as early as late March or early April, and remain active until late June or July. Many adults stay underground starting in July, but some remain active aboveground into August and September. However, we have found significant differences in levels of activity in the four years of study on the Elkhorn Plain. We have seen lizards active at the beginning of April, but cool, dry storms during April and May have kept lizard activity sporadic each year. On the Elkhorn Plain, adults are consistently active each day in June and are reproductive. In three of four years, adult activity was extremely low or nonexistent in July. In 1990, no adults were active all year, remaining underground for 21 months (Germano et al., unpub. data). Hatchlings from 1989 were active aboveground in April and May of 1990, but their activity decreased in June and only a few lizards were seen past the end of June. No reproduction occurred in 1990. In contrast, adults were active from late April through July in 1991, and several adults were active into September.

Few data exist on the reproductive capacity of blunt-nosed leopard lizards. Mating occurs between late April until June and oviposition generally occurs from late May until early July, but may occur as late as early August (Tollestrup 1982). Clutch size ranges from one to six with an average of about three eggs. Females can produce multiple clutches of eggs in favorable years (Germano and Williams, unpublished data).

Hatchlings often emerge by late July or early August, although they have been found as early as 1 July (Tollestrup 1982, unpublished data). They hatch at about 45 mm SVL and are noticeably spotted. Hatchlings are active into September, and sometimes October. We found hatchlings active until 24 October in 1991. Hatchlings grow rapidly and some reach small-adult size (85-95 mm SVL) by the end of the first growing season. During this time, they develop yellow coloring on the underside of the tail and the rear legs. Females may breed during their first spring, but males may not be able to breed until their second spring because they may not be able to obtain a territory (Tollestrup 1982, 1983).

FUTURE REQUIREMENTS FOR RECOVERY

The blunt-nosed leopard lizard continues to lose habitat throughout its range. The human population of California continues to grow, and the central valleys are experiencing unprecedented increases. As the human population increases, more agricultural land is converted to urban use. This, in turn, leads to more native land on

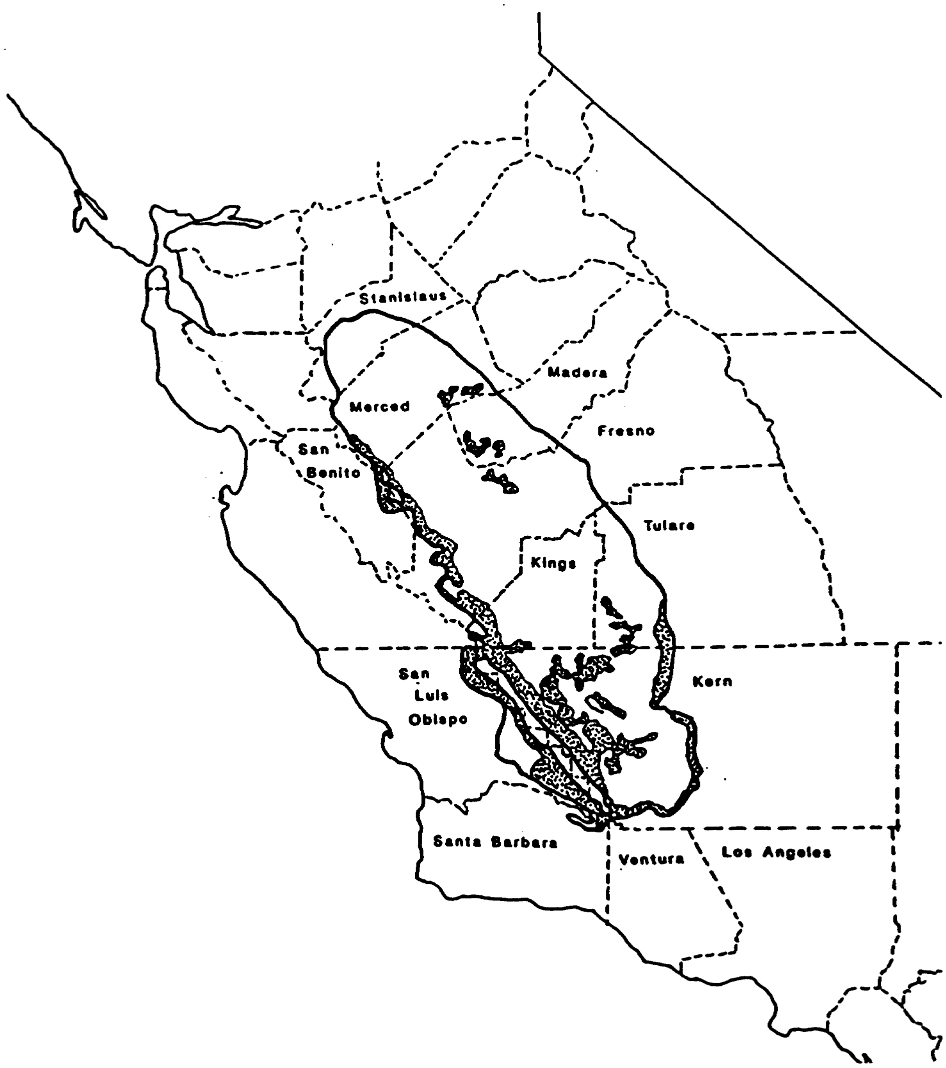

Fig. 1. Presumed historic (outline) and estimated present (stippled) distribution of the blunt-nosed leopard lizard (*Gambelia sila*). Presumed historic range is slightly modified from Montanucci (1965) and does not account for unused portion of the range within this outline due to inappropriate habitat. The present distribution is an estimate based on Tollestrup (1979b) and general knowledge of remaining range that could support blunt-nosed leopard lizards.

the west side of the Valley being converted to cultivated agriculture.

What remains unanswered is the amount of land needed to ensure the survival of the blunt-nosed leopard lizard as a dynamic, evolving species. It is doubtful that all remaining native habitat can be protected. Even if such were true, it is unknown whether this constitutes enough land to preserve this species. At present, the only way to determine how many individuals (or populations) are needed to reasonably ensure the continued existence of the blunt-nosed leopard lizard is to model the dynamics of populations. However, specific life-history data are needed before any confidence can be placed in model predictions. Recently, a population model was run on the best available data for the blunt-nosed leopard lizard (Buechner 1989). Although estimates of population viability through 50 years were constructed from this model, their accuracy was not considered to be good because no estimates of variation among individuals and regions could be included (Buechner 1989).

Two major efforts are needed immediately for recovery of the blunt-nosed leopard lizard. First, a status survey of the species' range is necessary. No status survey has ever been conducted, even though this species was first federally listed as endangered in 1967. Secondly, a comprehensive, long-term study of the demographics of valley floor and foothill populations of blunt-nosed leopard lizards needs to be started to determine minimum viable population size and the number of populations necessary for long-term viability.

Other important studies are also needed including morphological and genetic composition of leopard lizard populations at contact zones, morphological and genetic differences between valley and foothill populations, genetic makeup of blunt-nosed leopard lizards throughout their range, ecology of leopard lizards in contact zones, and food habits of this species among sites and years need to be studied. There also are more applied problems to resolve such as the effects on populations of grazing by cattle and sheep and spraying of insecticides, the species' natural ability to recolonize fallow fields, reintroduction methods, and the size and quality of habitat corridors needed to connect sustaining populations.

RECOMMENDED RESEARCH

It is recognized that no agency or institution has the funds needed to support all of the work needed. Some topics may best be investigated as thesis or dissertation topics. Several of these topics, however, should be studied immediately, and consideration should be given to funding these projects first. Below, research topics are listed by priority, and a brief discussion of how a study could be conducted and what results should be expected is presented for each.

Status Survey Throughout The Range

A distribution map of current and historic locations of the blunt-nosed leopard lizard has never been compiled. Such a map would help define habitat and population losses, habitat affinities, and edaphic and climatic limits of this species. Historic data would be gathered from the literature and museum records. Recent data would be plotted from the Natural Diversity Data Base (NDDB) and from contractor reports.

General Demographic Study of Valley Floor and Foothill Populations

Plots would be established in representative habitats and followed for three to five years using standardized methods (Germano et al., unpub. data). These data are needed to determine minimum viable population size. Populations should be studied in at least five areas; three populations on the valley floor and two in foothills. These efforts would give some of the variance necessary for accurately modelling the viability of this species.

Effects of Livestock Grazing on Populations

This is a vital study because grazing is nearly ubiquitous in the range of the blunt-nosed leopard lizard. The plots on the Elkhorn Plain are already designed to study these effects (Williams and Tordoff 1988), and with modification, plots on the Pixley NWR can used to follow this disturbance (Williams and Germano 1991). Studies designed to gather life-history data can be modified easily to gather additional information on the effects of grazing.

Genetic and Morphological Variation

Evidence of *Gambelia* hybridization suggest genetic and morphological studies are important in determining the status of populations throughout the range of the blunt-nosed leopard lizard. For example, a population of the blunt-nosed leopard lizard was found recently south of the California Aqueduct at the base of Grapevine Pass (pers. observ.). Grapevine Pass is considered one of the routes of dispersal of leopard lizards into the San Joaquin Valley (Tanner and Banta 1977). A morphological and genetic study of this population could add significantly to the systematic understanding of relationships among leopard lizards.

Food Habits

Some work on food habits of blunt-nosed leopard lizards has already been done (Montanucci 1965, 1967; Tollestrup 1979, Kato et al. 1987a). A focused study throughout the range of the lizard would show how diverse and variable is the diet of this species. Information should be gathered from both scats and from stomach-flushing individuals. Stomach flushing is a safe and practical method for determining the food habits of lizards before digestion occurs (Legler 1977, Legler and Sullivan 1979, James 1990). This work could occur during studies of the demography of populations throughout the valley.

Recolonization of Fallow Fields

Knowledge about the ability of this species to naturally recolonize fallow fields will be advantageous. Data should be collected on the rate of recolonization of fallow fields by blunt-nosed leopard lizards and the persistence of these populations. This information could help in deciding where to purchase land for preservation.

Effects of Spraying Insecticides

The California Department of Food and Agriculture (now part of CalEPA) has sprayed insecticides in the Central and Imperial Valleys for several decades to suppress beet leafhopper (*Circulifer tenellus*) populations. Part of this program involves spraying of native vegetation that support blunt-nosed leopard lizards in the southern and western portions of the San Joaquin Valley. Little is known concerning the direct or indirect effects of spraying insecticides in areas that support blunt-nosed leopard lizards.

Reestablishment in Habitat by Translocation

Sometimes it may be desirable to move blunt-nosed leopard lizards to new areas that currently do not have populations. Giant kangaroo rats (*Dipodomys ingens*) have been reestablished on one plot in the Carrizo Plain (Williams and Germano, unpub. data). Building artificial precincts may have been a key to the success of this effort with the rats. A study (or several) should be conducted to determine means by which leopard lizards can be similarly reestablished.

Size and Quality of Habitat Corridors

Species in many of the larger preserves that might be established in the valley may benefit by the creation of habitat corridors. These corridors would allow individuals to travel unimpeded between preserves or would support sustaining populations of less vagile animals. In the case of the blunt-nosed leopard lizard, natural genetic flow between preserves can only be accomplished by interconnecting populations. We do not have the information to know how narrow or long a corridor can be and still sustain this species. Key to understanding the size and shape of habitat corridors is information on dispersal distances, home range size, mating systems, and genetic makeup of populations. An effort should be made to quantify the characteristics of populations and their habitats that may be important to the design of corridors.

RECOMMENDED METHODOLOGY

Three different methodologies should be utilized depending on study objectives; environmental assessment, status survey, or basic research. Past recommendations for studying this species attempted to standardize methods for these different efforts (Tollestrup 1976). However, we believe that the differing objectives of each effort require different methods of censusing be employed.

The cruise method of censusing lizards (Degenhardt 1966), which has become the standard for censusing blunt-nosed leopard lizards (Tollestrup 1976), involves establishing an 8.1 ha (20 ac) plot with 16 census lines. Lizards are visually detected but not captured and marked. It was believed that blunt-nosed leopard lizards are too difficult to capture to conduct a mark-recapture study (Tollestrup 1976). A plot is recensused 10 times during the spring and early summer to determine a relative density of lizards. We believe that this method of censusing does not meet the objectives of either environmental assessment work, a status survey, or demographic research.

For environmental assessments, relative density is usually unimportant. A determination of presence or absence of blunt-nosed leopard lizards at a project site is all that is required. The constrictions of standardized plots are unnecessary and the quantification of density is more apparent than real. The same is true if this method were to be used for a range-wide survey. Time constraints would make the use of plots prohibitive, and many areas (i.e. linear habitats such as washes) do not lend themselves to plot design. Relative density can be obtained by comparing the number of lizards seen per unit time spent searching, and may have as much significance as densities determined using the cruise method.

The use of a census plot is valuable, however, for long-term research. In areas that will be repeatedly sampled over several years, plots are a convenient way to study a population. However, demographic analysis requires that absolute densities be determined, which requires significantly more effort than 10 censuses and requires lizards to be marked and recaptured.

Environmental Assessments

We suggest that small areas (<1/4 section) be searched systematically by walking meandering transects through blunt-nosed leopard lizard habitat. Distances between transects should be no greater than 60 m. An area should be searched for at least 6 days or until lizards are found. The aim simply is to detect the presence of blunt-nosed leopard lizards. Searches should be conducted in the spring and summer during optimum temperature regimes (see California Department of Fish and Game, Region 4 guidelines). For larger areas, censuses should be conducted by subsampling the project area. Searches should be made in all representative habitats.

Status Survey

The entire remaining range of the blunt-nosed leopard lizard needs to be surveyed. This effort will require searching a large area. Driving surveys are appropriate in some habitats. Many blunt-nosed leopard lizards are readily visible on the road or on rodent mounds sunning themselves. Every 1 km, the vehicle should be stopped and observers should get out and scan surrounding terrain with binoculars. Meandering transects should be used in areas that have limited road access. Optimum season and temperature regimes need to be followed. Areas of appropriate habitat where lizards were not found during initial surveys should be resurveyed at least twice more.

Long-term Research

Although it has been the standard protocol to census blunt-nosed leopard lizards on an 8.1-ha plot since the recommendations of Tollestrup (1976), size of the area sampled should be based on statistical considerations. We believe that a plot of about 8.1 ha often is barley sufficient to contain adequate numbers of leopard lizards for statistical comparisons while still being small enough to census during optimum daily activity of lizards. However, we find that the usual spacing of census lines (about 18 m apart) within the 8.1 ha plot is too wide under many circumstances to detect most or all lizards. Where there are many shrubs or when herbaceous ground cover is thick and tall, effective width of census lines may be no more than 10 m (5 m each side of the observer). Failure to detect most lizards reduces the precision of statistical elements and potentially introduces unwanted bias between plots with different amounts of plant cover. Central to any density estimate is a measure of effective sampling area, including edge around the plot. We recommend either determining strip width of census lines using fourier series estimator of sighting distances (Burnham et al. 1980) or spacing census lines at 10 m spacing to assure detection of all individuals on a plot. With accurate positioning of lizards on the grid, a nested subgrid routine (White et al. 1982) could be applied to census data to estimate effective sampling area.

CONCLUSIONS

Certainly the research topics proposed do not encompass all that could or should be studied in the next few years. However, these topics are critical to the recovery of the blunt-nosed leopard lizard. We should not be satisfied with the current knowledge about the biology of this species. Even though decisions must be made concerning conflicts between further development within this species' range and the species' continued existence, research should continue concurrently. We need to begin to address many specific questions about the biology of this species so that 10 years from now we are in a position to make more intelligent decisions than we can make now. Although much effort and money are expended by project proponents to mitigate impacts caused by specific developments, these mitigation measures often do not result in an increase in knowledge of the species affected. A mechanism should be created to direct a useful part of these monies to basic research on the affected species. In the long run, monies spent on gathering basic data on the biology of endangered species will benefit project proponents and will ensure the recovery of declining species.

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