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**FY 1992 Annual Report**

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**Captive Breeding of the Endangered  
Morro Bay Kangaroo Rat  
Dipodomys heermanni morroensis**

**Interagency Agreement 14-16-0001-90546  
between  
the U.S. Fish and Wildlife Service  
and the  
National Zoological Park, Smithsonian Institution**

**Prepared by  
Miles Roberts and William F. Rall,  
Co-Principal Investigators  
National Zoological Park, Washington, D.C.**

**January, 1993**

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## Recommendations

1. To maintain adequate body condition, and hence maximize reproductive potential, *D. heermanni* should be housed at temperatures at or near thermalneutrality (28°C-32°C).
2. Animals maintained at any temperatures on a dry food (i.e. concentrate) diet should have access to free water (i.e. either in bowls or in lettuce or other vegetation). This appears to be a necessary adjunct to enhanced intake.
3. Animals permitted access to food caches may maintain a higher plane of condition for longer than animals without cached reserves.
- 4. Because animals maintained within thermalneutrality are more active and display distinctly different behaviors and patterns of behavior than those at lower temperatures, the thermal environment may influence the location, rate and nature of social interactions.
5. If animals are exposed to temperatures below the lower critical temperature, they should be provided with a sufficient quantity and quality of nest material to be able to construct nests that will reduce conductance and enhance energy conservation (i.e. to buffer against low temperatures).
6. Thermal "therapy", coupled with a high plane of nutrition, may be a useful tool for improving body condition in some animals in poor or marginal condition.
7. Animals should be housed under conditions where they have visual, olfactory, auditory and possibly tactile contact with conspecifics. Housing under such conditions improves body condition, potentially increases the rate of female cycling and results in reduced levels of aggression during breeding or other social encounters.
8. Pairs (i.e. an adult male and female) may be housed together in large seminatural enclosures for long periods without adverse effects. Animals housed in this way must be provided with a large number of nest and food cache sites and visual barriers to reduce aggression and conflicts over resources.
9. Consistent behavioral differences among male reproductive and social performance are readily apparent and only a very small proportion of males in captivity display behavioral patterns that suggest they will successfully breed in captivity. It may be possible to identify "stud" male using the behavioral screening techniques described in this report. However, a large pool of males must be available to produce even a small number of breeding individuals.
10. Experiments involving the administration of exogenous gonadotropic hormones suggest that an estrus-like condition may be induced in females and copulations may ensue. This procedure should be evaluated further as a means may for "training" and habituating males and females to sexual interactions.

11. Successful reproduction appears to be a function of the number of "stud" males, the number of reproductively active females, the conditions under which they are housed, and the capabilities and interest of the personnel caring for the colony. Hence, we recommend that the breeding program be relocated to a facility that has ready access to wild populations from which additional suitable animals may be readily obtained and "surplus" animals may be released and which can care for the animals in a manner consistent with recommendations 1-10 (above) and those indicated in our previous annual reports. The captive breeding population should be "open" and essentially contiguous with wild source populations. This will be extremely important in overcoming stochastic sampling difficulties which have apparently hampered efforts to obtain sufficient breeding quality animals in the past. It will also prove to be critically important when later reintroduction efforts are undertaken.

We recommend that the selected facility be in California for several reasons: 1) It meets the requirement of close proximity to source populations of animals as discussed above; 2) It places the breeding facility within close geographic proximity to the largest available concentration of expertise on kangaroo rat biology; 3) It places the project near to its management authority (i.e. USFWS, Ventura office). Finally, because of 1) - 3) a California base would provide for expansion to accommodate short- or long-term research and/or conservation projects with other species of *Dipodomys* in the future. With no fewer than six forms of heteromyid rodent in Region 1 being listed as endangered or threatened, it should be readily apparent that there will be future demand for captive breeding expertise and housing beyond that currently required for *Dipodomys heermanni morroensis* ■

### Acknowledgements

We would like to thank George Ritchotte, Cathi Mathias, Mike Deal and Frank Kohn for animal care and Jamie Goldfarb, Sergio Harding, Jerry Harris and Matt Cham for research assistance. Lisa Tell and Scott Citino provided medical care, Dick Montali and Don Nicholls performed necropsies. Karen Otiji and Betty Howser provided administrative support. We are grateful to Michael Robinson, Director of the National Zoological Park, for permission to conduct this research.

## Summary

1. The history of the Morro Bay Kangaroo rat captive breeding program, from its inception in 1984 through September 30, 1992 is summarized. The single breeding colony has been housed in three different locations: the California Polytechnic State University in San Luis Obispo, California (1984-1989), the U.S. Fish and Wildlife Service Research Station at Piedras Blancas, California (1989- 1991) and the Department of Zoological Research, National Zoological Park, Washington, D.C. (1991-1992). Eleven litters of *Dipodomys heermanni morroensis* and 13 litters of *D. h. arenae* were born at Cal Poly, a single litter was born at Piedras Blancas and two litters were born at the National Zoological Park. The studies conducted on reproduction, social and breeding behavior, growth and development, physiology, nutrition, energetics, communication systems, medical and husbandry requirements of captive *D. heermanni* are discussed.

2. Changes in females vaginal morphology during the reproductive cycle were correlated with changes in urinary hormone levels to assess the effectiveness of morphological indicators as predictors of estrus. The urination procedure employed was an efficient and effective way of gathering urine from female kangaroo rats. Trained females urinated quickly and showed few signs of distress during the procedure. Peak levels of LH in one female (110041) coincided with the presumed time of estrus based on external morphology. However, it was difficult to determine whether the observed increase in LH was a random fluctuation or was indicative of a preovulatory hormone surge. Of nine females examined, two never entered peak estrus. These females are in excess of 5 years of age and are likely postreproductive. The remaining seven females appeared to be reproductively active. Cycle length was calculated for 12 cycles from 6 females. The median cycle length was 9.5 days (range 6-20 days). Mean individual cycle length for the six females ranged from 6.3 to 20 days.

3. Previous studies have shown a tentative link between body condition and reproductive condition in *Dipodomys heermanni* (Roberts and Rall, 1991). Body weights of captive *D. heermanni* fluctuate seasonally, producing concomitant changes in body condition (condition index or CI, estimated as the ratio of body weight to body length). Rate of estrus cycling in *D. heermanni* has been shown to vary with CI, with some females ceasing show reproductive cycling when their CI was low. This suggests that heavy females may be more likely to be reproductively active than light females. Experimental studies showed that housing conditions have measurable effects on body weight. Moving an animal from a solitary situation to one in which visual, olfactory, auditory and tactile communication with conspecifics of the opposite sex is permitted can result in an increase in weight. These effects appear more pronounced in females, and occur within days of a change in housing.

4. The captive breeding of *Dipodomys* is problematic. When housed together, kangaroo rats often become highly aggressive; injury or death sometimes results (Roest, 1988; Rathbun et al., 1990). Because of this extreme aggression, attempts to breed kangaroo rats have frequently used the technique of dyadic encounters (placing a male and female together in a small enclosure for a limited period of time under close supervision). Familiarity may be a critical factor in determining pair compatibility and eventual reproductive success. Therefore we attempted to assess the effect of familiarity on behavior of male and female *Dipodomys heermanni arenae* during dyadic encounters. Strangers fought significantly more often and for longer than familiar pairs.

Attacks occurred in 25% of encounters between familiar animals and 100% of encounters between strangers. While many factors remain to be investigated, it is clear that familiarity has a profound influence on the nature of social interactions among male and female *D. heermanni* in captivity.

5. Based on the results of (4), two questions were examined with a view towards devising appropriate breeding protocols for *Dipodomys heermanni*. First, we examined whether familiarity is achieved on a time scale of days, weeks or even longer. Second, we assessed whether familiarity inevitably promotes compatibility or whether other factors are also involved? We found that while familiarity was a critical factor in pair compatibility, familiarity alone did not guarantee that a given pair would show behavioral tolerance. The following strategy for establishing successful pairs is recommended. Males and females should be allowed to live side by side in a situation similar to the wooden caging complex described. After several weeks of such indirect exposure, potential pairs should be screened for compatibility. Incompatibility should be evident within five minutes of introduction. Compatible pairs may then be released into large enclosures permitting continuous access but allowing each animal to escape unwanted interaction. An alternative strategy would be to monitor the reproductive condition of females on a daily basis and to allow compatible pairs to interact on a daily basis during periods of apparent estrus. The first strategy requires a great deal of space, but allows the animals unrestricted access to each other during periods of female receptivity. The second method is labor intensive and does not ensure that pairs will have access to each other when the female is ready to copulate.

6. Attempts to establish breeding colonies of kangaroo rats (*Dipodomys spp.*) have met with little success (Day et al., 1956; Butterworth, 1961; Daly, et al. 1984; Rathbun et al., 1989, 1990; Roest, 1991). Only a subset of apparently sexually mature individuals actually copulate and produce offspring. Lack of breeding competence has been reported for both sexes, but is especially pronounced in males. The factors determining male reproductive competence are unknown. We attempted to determine whether the behavior of individual male kangaroo rats differed in predictable ways, and to evaluate whether differences in behavior could be used to predict reproductive success. Consistent behavioral differences among males were readily apparent. Males differed significantly in the frequency with which they approached females and the frequency with which females avoided them (departed). They also differed in the frequency and duration of attacks. Using principal components analysis, three components explaining 90.2% of the total variance were identified. The first component was positively associated with male approaches, female departs and attack frequency and duration and was negatively associated with female approaches and male departs. This component was interpreted as male dominance. The second component was highly associated with attack frequency and duration and negatively associated with contact frequency and duration. It was interpreted as aggression. The third component, which was highly associated with female approaches and male departs, was interpreted as female dominance. Analyses of variance performed on the three principal components indicated that only the first component, male dominance, differed significantly among the males.

7. Previous studies determined that *Dipodomys heermanni* at NZP housed at 23°C and fed *ad lib*, self selected diets did not deposit significant fat reserves (Roberts and Rall, 1991) suggesting that they may have difficulty mobilizing sufficiently energy for reproduction. Size and condition-based life history theory suggests that individuals in marginal or poor body condition, having virtually no reserves to devote to reproduction,

may "choose" to significantly reduce, or even forego, energetic expenditures on reproduction. At the National Zoological Park, *D. h. morroensis* and *D. h. arenae* females in less than average body condition cycled significantly less frequently than animals in better body condition (Roberts and Rall, 1991). Thus, it is clearly possible that there may be a critical link between the thermal environment in which animals are maintained, their body condition and their rates of reproduction. The purpose of this experiment was to examine changes in food consumption rates, body condition and behavior in two groups of individuals housed under two different thermal regimes, one below the thermal-critical temperature and another within thermal neutrality. No significant difference in mean weights changes were found between the two experimental groups in the short-term as the increased energetic demand of the lower temperature was apparently compensated by increased intake. However, the low temperature group responded to the lower temperature regime by becoming less active and spending a higher percentage of time inside nestboxes that had more complex nests and were marginally warmer, relative to ambient temperatures. Over the longer term, however, the high temperature group achieved better condition than the low temperature group. This was in part due to weight gain and greater food consumption by the high temperature group but also to a significant weight decline, possibly as a result of reduced food intake, in the low temperature group. This suggested that the high temperature group acclimated successfully to the higher temperature regime and was able to increase body mass even while reducing overall food intake and displaying relatively high levels of activity. Conversely, the low temperature group did not acclimate well enough to even maintain starting weights. Management implications of these findings are discussed ■

# Historical Review of the Morro Bay Kangaroo Rat Breeding Program

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The Morro Bay kangaroo rat, *Dipodomys heermanni morroensis* (henceforth: "*morroensis*"), was designated an Endangered Species in 1970 and the Morro Bay Kangaroo Rat Recovery Plan was subsequently published in 1982. Among the steps designated by the Recovery Plan as necessary for the subspecies' recovery was a rapid increase in population size via captive breeding to provide founder stock for subsequent reintroductions to recovered or restored habitats and translocation of *morroensis* from threatened to secure habitats, if these could be found. Both sets of recommendations implied that wild-caught *D. h. morroensis*, *arenae*, and possibly other forms of *D. heermanni* may have to be held in captivity for either short (e.g. for translocations) or extended periods (e.g. in the case of a captive breeding colony). Sections of the Recovery Plan relevant to captive breeding and reintroduction are given below.

## **2. Maintain and enhance Morro Bay kangaroo rat populations.**

### **25. Artificially increase Morro Bay kangaroo rat populations.**

- 251. Determine feasibility and techniques for breeding and release of captive bred animals into the wild.
  - 2511. Continue research on captive breeding of *D. h. arenae*.
  - 2512. Establish captive reared *D. h. arenae* in Arroyo Grande-Point Conception area.
- 252. Develop a Morro Bay kangaroo rat captive breeding program.
  - 2521. Capture Morro Bay kangaroo rats from the wild.
  - 2522. Breed Morro Bay kangaroo rats in captivity and produce young for release to the wild.
- 253. Re-establish wild populations of Morro Bay kangaroo rats.
  - 2531. Select and prepare release sites.
  - 2532. Release captive-reared Morro Bay kangaroo rats into selected habitats.
  - 2533. Protect released animals.
  - 2534. Monitor the released animals to assess the success of the program.
- 254. Translocate wild Morro Bay kangaroo rats to selected habitats on protected public lands, if necessary and appropriate.
  - 2541. Capture wild Morro Bay kangaroo rats from unprotected private lands.
  - 2542. Select and prepare release sites.
  - 2543. Release wild animals on public lands.
  - 2544. Protect released animals.
  - 2545. Monitor released animals to assess the success of the translocation.

[Extracted from the Morro Bay Kangaroo Rat Recovery Plan, 1982]

The captive breeding program for *D. h. morroensis* formally began in 1984 when Aryan Roest, a Professor of Biology at the California Polytechnic State University (Cal Poly) in San Luis Obispo working under contract with the USFWS, founded a captive colony at that institution. Five wild-caught *morroensis* founded the colony in 1984, four more were added in 1985 and a final one was captured in 1986. Eight of these animals were obtained at the Bayview site, one from the Junior High site and one from the Buckskin site.

Between 1984 and June 1988 11 litters of *morroensis* comprising 31 offspring were born at Cal Poly (mean litter size = 2.8; an annual recruitment rate of 7.8 captive-born animals per year). Seven of these litters were conceived in captivity and four were wild conceived captive births. However, reproduction occurred in only five of the 11 wild-caught animals. Breeding efforts were terminated due to lack of funding in June 1988. In January 1989 Roest transferred 21 *morroensis* to U.S. Fish and Wildlife Service at Piedras Blancas. At the time, the captive *morroensis* population was approximately twice the size of the founder population established four years earlier representing a net annual population growth rate of approximately 18%. The mean annualized mortality rate in the *morroensis* colony had been approximately 13% per year.

—Prior to establishing the *morroensis* colony, Roest obtained wild caught *D. heermanni arenae* (henceforth: "*arenae*") from the Lompoc area to begin experimental captive breeding with the subspecies believed most closely related to *D. h. morroensis*. The *arenae* founder population comprised nine animals.

The most intensive breeding efforts with *arenae* occurred between 1983 and June 1988. During this period, 13 litters were born (34 young; mean litter size of 2.6; an annual recruitment rate of approximately 6.8 captive-born animals per year); twelve litters were captive conceived and one was a wild-conceived captive birth. At the completion of the Cal Poly phase of the captive breeding program in January 1989, Roest's *arenae* colony consisted of 14 animals. This represented a net annual population growth rate of approximately 9%, or about half that achieved for the *morroensis* colony. The mean annualized mortality rate in the *arenae* colony was approximately 14% per year.

Kangaroo rats are notoriously difficult to breed in captivity but Roest's success in breeding the two subspecies of *D. heermanni* rivaled the best efforts at breeding *Dipodomys* in captivity (e.g. Day et al, 1956; Daly, Wilson and Behrends, 1984). The fact that the captive breeding effort at Cal Poly was mostly student-driven made this accomplishment all the more remarkable. Roest was apparently underfunded and had to rely to a large extent on undergraduate students to care for animals and conduct research projects. Between 1983-1989 six student papers, mostly senior theses and special project reports, were completed on various aspects of behavior and reproduction of both *morroensis* and *arenae*. Roest also submitted four annual reports and several quarterly reports and project updates to FWS during the course of his stewardship of the project. While most of these data remain unpublished, they constitute an extremely valuable corpus of knowledge on the techniques and conditions prevailing at a time when colonies of both subspecies were successfully reproducing. Some of this information has recently been published (Roest, 1991).

As mentioned previously, Roest's efforts were rather seriously underfunded. This factor, and other competing professional demands, prompted him to inform USFWS in early 1988 that Cal Poly's involvement in the project would end and alternative arrangements for housing the *morroensis* and *arenae* colonies would have to be made. While efforts to breed animals at Cal Poly had essentially ceased by mid-June 1988, it took until mid-January 1989 for new arrangements to be made. The remaining 21 *morroensis* and 14 *arenae* were transferred from Cal Poly to Galen Rathbun at the USFWS Piedras Blancas Research Station.

Rathbun's decision to take on the breeding project was based on his hypothesis that a more "natural" approach to captive breeding might lead to even greater productivity. Rathbun's intention was to maintain kangaroo rats at Piedras Blancas in a manner somewhat more consistent with their natural environmental requirements and to minimize human disturbance. The colony was maintained in a 30' X 30' room in an outbuilding at the Research Station in six large wooden breeding cages (five were 6' X 12' and another approximately 8' X 10'). Each breeding cage was divided in half by a 2' high partition with a connecting door to allow separation of the sexes as necessary. Enclosure floors were provided with a series of Masonite baffles arranged in a maze-like fashion to increase the complexity of the habitat and provide visual barriers.

Test-breeding encounters involved only *arenae* introduced at various stages of the estrous cycle under constant observation. Introductions under these conditions resulted in a high level of aggression and even some fatalities. In an attempt to find a successful encounter strategy, Rathbun subsequently attempted to duplicate the technique successfully used by a Mr. Potter of Creston, California in which several *arenae* were placed in a 15-gallon aquarium and reproduced after a period of intense social equilibration. After two unsuccessful attempts with this method, Rathbun abandoned it because of the high likelihood of injury or fatality.

In mid-March, 1989 Rathbun's group began monitoring estrous condition of *arenae* and *morroensis* three times per week (using the techniques described by Villablanca, 1987) and ran breeding encounters only when females were in or approaching estrus. Again, animals were continuously under observation during introductions in the large enclosures and were separated at other times. This technique showed much more promise than the "cold" introduction approach but unfortunately the number of females clearly cycling was small and the frequency of their cycles was quite low. Nevertheless, between early May 1989 and mid-January 1990, 40 breeding encounters of *morroensis* had been run. Four copulations, but no births, resulted.

Mortality resulting from aggression, disease and unknown causes was rather high between January 1989 and January 1990. In all, eight *arenae* and 14 *morroensis* died from a variety of causes. The *morroensis* colony declined from 21 to seven individuals (67% decline) and the *arenae* colony from 14 to six individuals (57% decline). A number of the carcasses were preserved after autopsy and were sent to the National Zoological Park where they are stored in the Molecular Genetics Laboratory at -70°C.

In January 1989, funding for the project at Piedras Blancas was reduced to a level that permitted only a maintenance level of care and attempts to breed animals effectively ceased. At this time, Rathbun concluded that the failure to successfully breed *D.heermanni* may be attributed to advanced age and small size of the colony, a high rate of male impotency, high levels of aggression during pairings, and male/female incompatibility. He recommended that a more intensive program of monitoring for estrus be undertaken and that the colony be relocated to a site where more and better resources could be brought to bear on the problem.

In mid-January 1989, the Ventura Office of USFWS approached the Captive Breeding Specialist Group (CBSG) of IUCN to help them locate an institution willing to take the *arenae* and *morroensis* colonies and continue the breeding effort. U.S. Seal, Head of CBSG, circulated a memorandum to a number of zoo specialists requesting comments and/or assistance. The comments he received generally voiced extreme pessimism regarding the prospects of breeding this species in captivity and saving it

from extinction. However, the National Zoological Park (NZP) expressed interest in attempting an intensive reproductive evaluation/breeding effort if additional wild-caught *arenae* could be obtained for surrogate studies.

In early March, 1989, NZP submitted a preliminary proposal to FWS for taking on the project. Unfortunately, protracted intra- and inter-agency negotiations on the Memorandum of Understanding continued until October 1989 and the colony was not transferred until November 1990. In the interim (January-November, 1990), animals were being held only on a maintenance protocol at Piedras Blancas because of funding/manpower shortages no breeding encounters could be run.

There were several reasons for NZP's interest in this project. The Department of Zoological Research (DZR) had for years maintained breeding colonies of many species of rare and unusual small mammals and it was felt that their unique mix of facilities, knowledge and experience might lead to the enhancement of captive breeding as suggested by Rathbun. Captive breeding efforts to date were done "on a shoestring," it was felt that an institution like NZP could bring to bear a much wider array of human and other resources in critical areas such as nutrition, reproductive physiology, veterinary care, genetics and developmental and reproductive behavior. NZP was also potentially in a position to evaluate, and if necessary apply, "high tech" methodologies, such as gamete recovery and cryopreservation, hormonal therapies and embryo transplantation, to the captive breeding problem.

In November 1990, NZP received seven *morroensis* (four males and three females or 4.3) and six *arenae* (4.2) from USFWS Piedras Blancas. All of these animals were captive born at Cal Poly. The *arenae* were between 42 and 55 months of age and the *morroensis* between 40 and 53 months of age. The *arenae* colony was subsequently supplemented with 11 wild-caught animals in April, 1991 (7.4) and eight more wild caught animals in October, 1991 (3.5). The supplemental animals were estimated as at least one year old but their exact ages could not be determined.

Animals were housed in a number of enclosures at NZP. Basic housing units were 10 gallon aquaria located in either large animals holding rooms (12' X 14') in a the "Tarsier Building" (a large indoor-outdoor animal building adjacent to the main DZR building) or in climate control rooms (10' X 10') in the Research Building (Figures 1-3). Animals were "socialized" in wooden enclosure units of approximately the same linear dimensions as 10 gallon aquaria partitioned from adjacent enclosures by mesh sides which permitted social contact across a barrier (Figures 4 and 5). Some animals were also given free-run of one of the large animal rooms which had been converted to semi-natural conditions (Figure 3). Introductions were run in home aquaria and a variety of neutral arenas (eg. Figure 6) and some animals were paired for long periods in the large converted animal room. Between November 1990 and January 1992, animal care for the colonies and introductions were conducted principally by a technician hired under the Cooperative Agreement with relief animal care was provided by keeper staff of the Department of Zoological Research. Beginning in January 1992, all animal care responsibilities were transferred to DZR keeper staff to permit Cooperative Agreement funds to be used to contract research with Dr. Katerina Thompson, a behavioral biologist with experience in rodent reproductive behavior. This approach facilitated the progress of important research in the husbandry, behavior and social facilitation of reproduction.

The initial stages of research at NZP focused on biomedical and husbandry requirements. All animals were given complete physical examinations and reproductive evaluations soon after arrival. Immobilization and physiological norms were established, and disease, parasite and other medical screenings were performed. A procedure was also established for the rapid and thorough necropsy of all dead specimens to ensure an understanding of cause of death and disease etiology. A protocol for preserving dead specimens for future genetic and morphologic study was also developed.

The following results were achieved in the first year of the study:

1) Quarantine, immobilization, and physical examination procedures applied to the colony were determined. Medical histories, necropsy reports, haematological values, blood and intestinal parasite findings and treatments were summarized.

2) Housing, environmental, and husbandry conditions were described including thermal and photoperiodic regimes, cleaning and feeding procedures, weighing, measuring and urine collection techniques, handling and restraint procedures and record keeping methodology.

3) A detailed diet intake study was conducted which suggested that there were significant differences in diet preferences between the *arenae* and *morroensis* individuals. This study also indicated the original diet to be deficient in calcium and manganese and that the calcium:phosphorus ratio of the consumed diet was inappropriate. The appropriate diet adjustments were made.

4) A method for determining relative body condition in colony animals was devised (the Condition Index or CI). Body condition varied considerably among individuals but showed synchronized, phasic changes (of approximately a 200 day period) within the colony that were independent of temperature and photoperiodic cycles. Animals with low CIs had a significantly higher probability of mortality and females in low CI classes (estrous) cycled significantly less frequently than females in high CI classes.

5) An experimental study of the responses of wild caught and captive-born *Dipodomys heermanni* to predator odors suggested that captive born animals may not be able to discriminate predator from conspecific odors, nor do they show appropriate predator avoidance behaviors when presented with predator odors. These findings suggest that captive born animals may have to undergo anti-predator training in preparation for reintroduction.

6) Methods for monitoring estrous cycles behaviorally, morphologically and hormonally were developed. Preliminary findings suggest that changes in vaginal morphology usually associated with estrous cycling could occur in the absence of correlative changes in some reproductive hormone levels. This suggested that morphological changes alone may not be reliable estimators of reproductive condition. The number, frequency, and periodicity of estrous cycles in the colony was reported and these data were compared with female weight, body condition, time of year, and prevailing temperatures. These data suggest that the mean monthly estrous cycle rate was highly positively correlated with female weight (and condition) and that female weight (and condition) is highly negatively correlated with month. A multiple regression model that included terms for weight, month and an interaction term between these two variables accounted for 91.2% of the variation in mean monthly estrous cycle frequency.

In the first year (ending September 30, 1991) 61 estrous cycles were detected and 50 introductions were conducted (32 with *morroensis* and 18 with *arenae*). Four of the *arenae* introductions resulted in attempted matings with intromission and/or ejaculations. No pregnancies resulted. Introductions were attempted in many different enclosures including home aquaria, neutral arenas and large semi-natural rooms.

7) Respirometry studies of four *morroensis* clearly indicated that the typical temperatures at which the colony had been held at NZP and elsewhere (approximately 23-25°C) was substantially below this subspecies lower critical temperature. The data suggested that at 26°C individuals may expend 10-20% more energy to maintain a constant body temperature than they would when held within thermal neutrality. The net (short- and/or long-term) effect may be a reduction in condition over time with a concomitant reduction in the rates of (estrous) cycling, conceptions and births, and may increase the probability of condition related illness and mortality.

8) The behavior of the two subspecies during introductions at NZP was found to be similar with that previously described elsewhere and for other *Dipodomys* species. As had been reported in other studies, levels of aggression were high between potential mates and introducees and there considerable variation existed (especially among males) in sexual receptivity and responsiveness (e.g. the "stud" male effect). There was evidence that direct and/or indirect social contact may facilitate reproductive behavior through the reduction of agonistic behavior, but there were too few data to draw firm conclusions about this.

Research in the second year were directed at experimentally determining factors most conducive to enhancing reproductive cycling and facilitating successfully courtship and mating behavior. Projects were conducted on the effects of the thermal environment on condition and reproductive potential, morphological and hormonal correlates of estrous cycling, social influences on body weight and reproductive condition, and the effects of socialization on reproductive behavior.

Year 2 results included the following:

1) A relationship between environmental temperature, food intake, activity and body condition was established experimentally. Animals maintained at temperatures within thermalneutrality (HT) consumed more food and were more active than those maintained below the lower critical temperature (LT). Consequently the HT animals gained weight and the LT animals lost weight. The results suggested that environmental temperatures could significantly effect such body mass based life history characteristics as longevity and the rate of sexual cycling and reproduction and could also possibly effect the frequency and nature of social interactions.

2) A relationship between housing conditions and/or social exposure and body weight was experimentally demonstrated. Animals moved from solitary conditions, without olfactory or auditory contact with conspecifics, to social enclosures where such contact was possible increased in weight. These effects were more pronounced in females than males and occurred within a few days of the change in housing conditions. These results suggested possible social effects on reproduction, via enhancement in body condition.

3) Significant effects of prior social exposure on dyadic behavior were experimentally demonstrated. Strangers were shown to fight more often and for longer than individuals who had been exposed to one another across a mesh barrier. Levels of aggression tended to subside over time as individuals became more familiar with one another suggesting that a few days of pre-exposure prior to actual introduction may facilitate mating behavior.

4) The "stud male" phenomenon was examined in detail to determine whether males could be classified as likely breeders on the basis of behavioral differences during encounters with females. Principle components analysis of eight behavioral categories resulted in the classification of males along a subordinate/friendly to dominant/aggressive component continuum. The only male to have copulated with females in prior encounters was classified as subordinate/friendly while a completely incompatible male was classified as dominant/aggressive.

5) Between October 1, 1991 and September 30, 1992, 146 introductions were conducted, all with *arenae*. Two of these resulted in copulations but there were no pregnancies. However, most of the introductions were made with anestrus females during social facilitation experiments, so copulations were not necessarily expected. The *morroensis* females were no longer cycling in the second year and consequently no introductions were attempted with them.

It became abundantly clear during the course of the second year that breeding success would be limited, at best. While it was felt that the array of resources of NZP brought to bear had substantially increased basic understanding of kangaroo rat captive management requirements, sustained captive breeding was still an unattained goal. Lack of ready access to fresh animals, relative little first-hand exposure of staff with the natural history of kangaroo rats, lack of contact with the west coast nexus of kangaroo rat biologists and the remoteness of the facility to the *in situ* conservation efforts were among the perceived handicaps of this effort. These shortcomings were also perceived to be handicaps for any captive breeding effort outside of the naturally occurring range of kangaroo rats. Therefore, NZP investigators concluded that the *ex situ* program should be relocated to California to an institution that could bring resources similar to those available at NZP to bear on the problem but which would also have substantially greater connectivity with the *in situ* program and regional academic and conservation networks. In mid- 1992, discussions were initiated with Dr. Sonja Yoerg to transfer the NZP colony and responsibility for the *ex situ* program to the University of California at Berkeley. Dr. Yoerg prepared and submitted a proposal to this effect to FWS/Ventura in the fall of that year. At this time, approval of the proposal appears to be contingent on funding ■

Figure 1

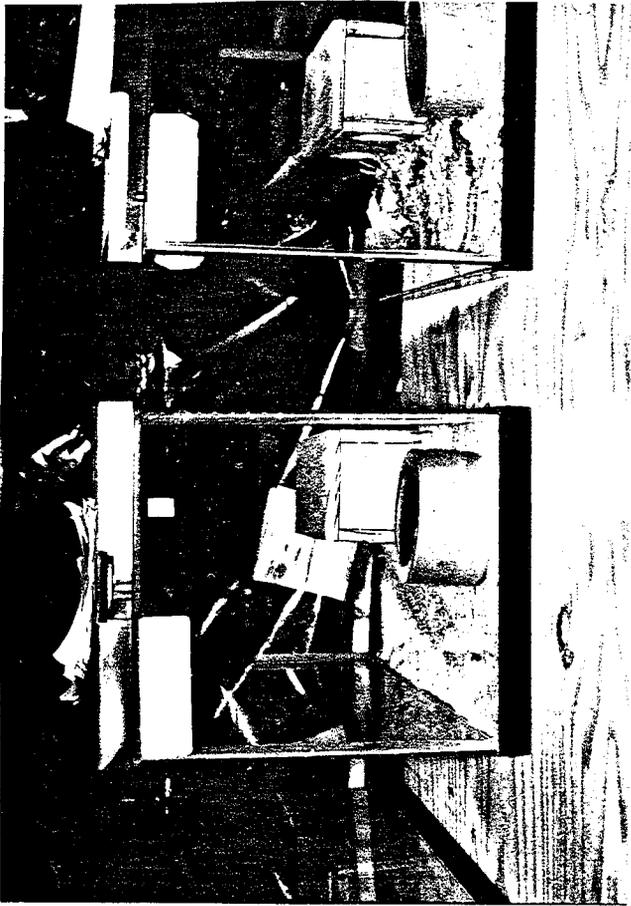


Figure 3

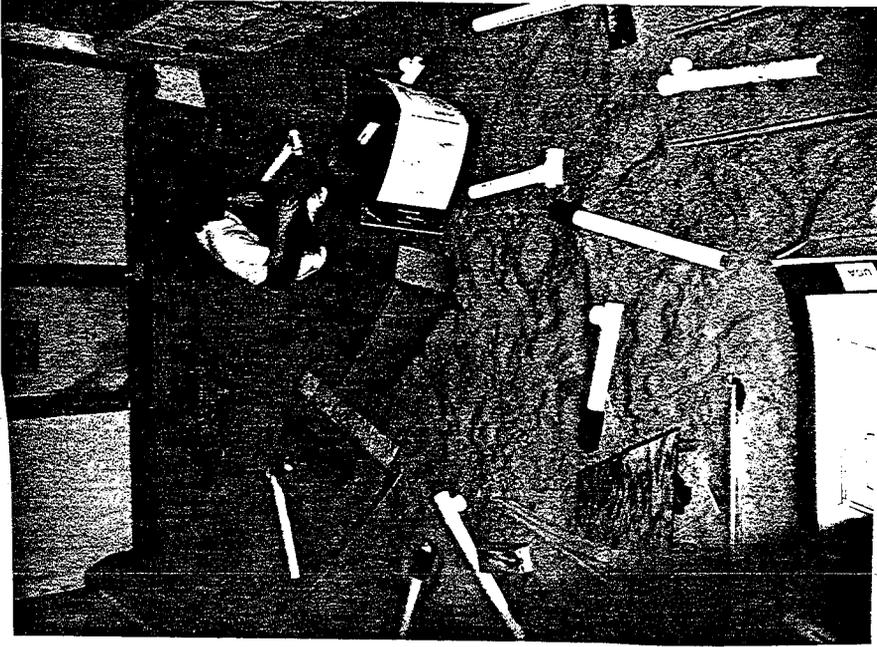


Figure 2

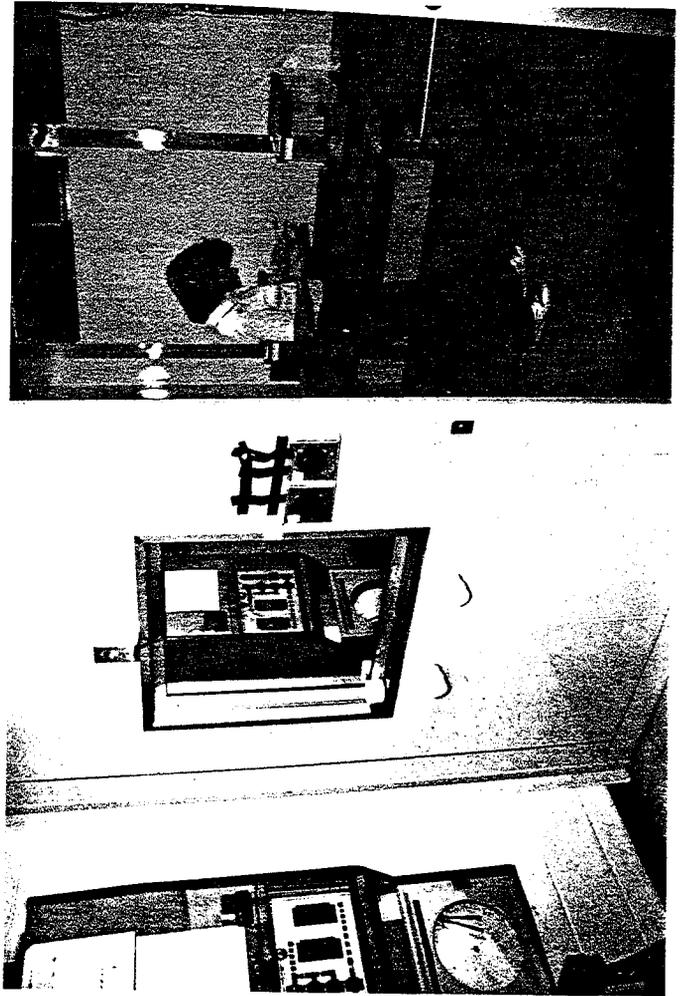


Figure 6

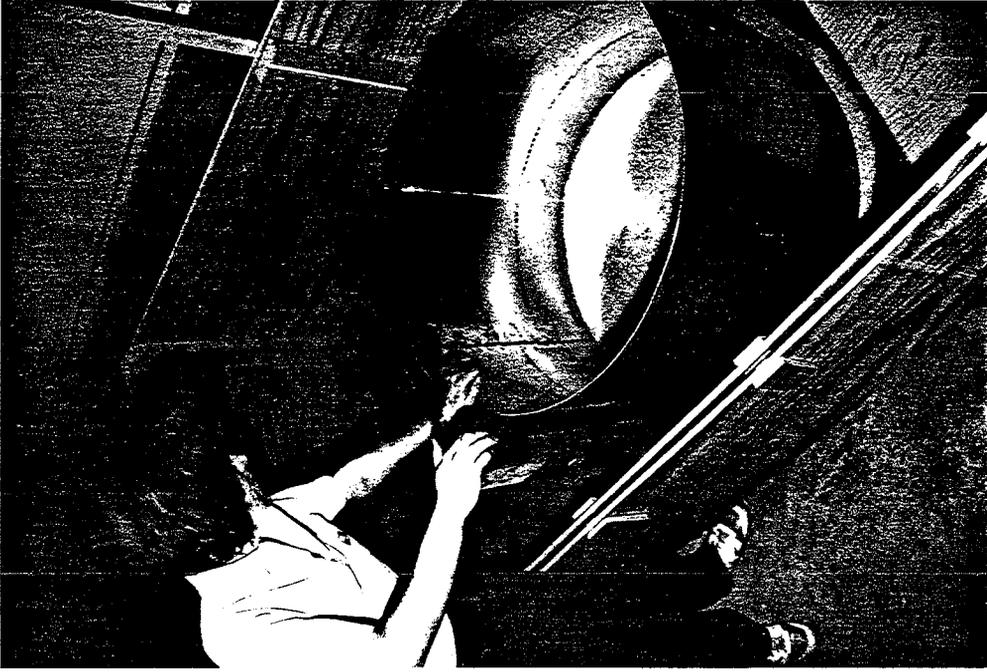


Figure 4

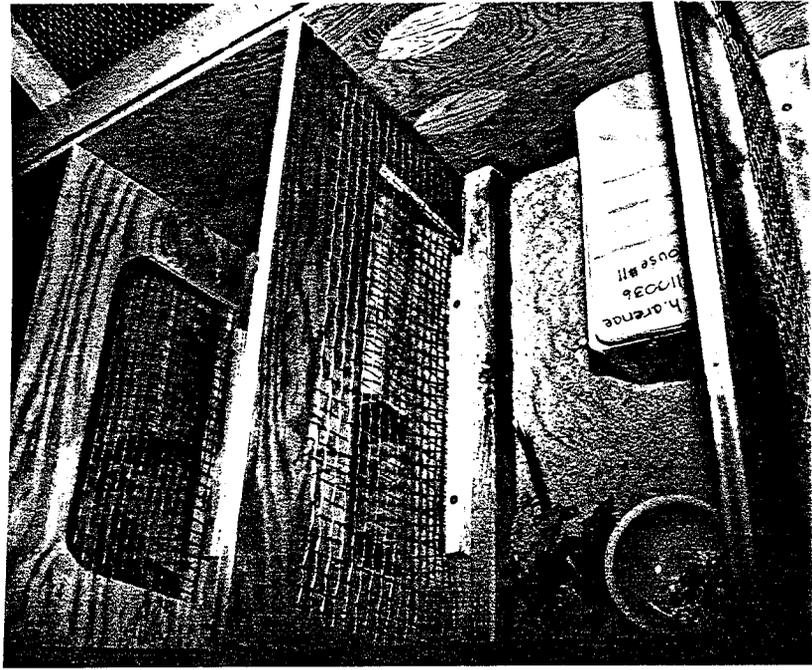


Figure 5

## Morphological and Hormonal Correlates of Estrous in Dipodomys heermanni

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The purpose of this study was to correlate changes in female, vaginal morphology during the reproductive cycle with changes in urinary hormone levels to assess the effectiveness of morphological indicators as predictors of estrus. We also wanted to evaluate the urine collection procedure to determine whether there were negative behavioral consequences of longterm urine collection.

### Methods

Estrus cycle length was determined by checking females on a daily basis. The stage of estrus was determined by rating the degree of vulval swelling and perforation of the vaginal membrane as described by Roberts and Rall (1991) using a scale of 1 to 5, with 1 signifying anestrus (no swelling, imperforate) and 3 representing peak estrus (maximal swelling, perforate). Estrous cycle lengths were measured by calculating the number of days between consecutive periods of peak estrus. Occasionally, females would be rated "3" for several consecutive days. In such cases, the first day of peak estrus was used in estrous cycle length calculations.

An attempt was made to collect daily urine samples from nine females for 34 consecutive days (6 July 1992 to 9 August 1992) to hormonally characterize estrus. Eight of the females sampled were *D. h. arenae* and one was a *D. h. morroensis*. One *arenae* female never urinated on 12 consecutive attempts to collect urine and appeared very agitated by the urine collection procedure. Consequently, she was dropped from the sample group.

To collect urine, kangaroo rats were placed individually in 40 x 60 x 37 cm high plastic bins covered with plexiglass lids to prevent escape. The floor of the bins were covered with plastic liners for ease of cleaning. After urinating, kangaroo rats were given their nestboxes, allowed to enter and promptly returned to their home cages (See Figures 7 and 8). Females that did not urinate after five minutes were likewise removed from the bin and returned to their home cages. Plastic liners were cleaned thoroughly with methanol between trials to prevent contamination. Urine was collected with a pipette and stored in plastic vials at -20°F for future hormone analysis. Urine volume was estimated by comparing samples to samples of water of known volume; samples were assigned to one of four volume categories: 50, 100, 150 or 200 microliters. Urine concentration was estimated by rating subjectively each urine specimens on a scale of 0 (colorless) to 3 (dark yellow).

## Results

### Estrous cycle length

Of nine females examined, two never entered peak estrus (females 109825 and 109832). These females are in excess of 5 years of age and are likely postreproductive. The remaining seven females appeared to be reproductively active. Cycle length was calculated for 12 cycles from 6 females. One female entered estrus only once, so a cycle length could not be calculated. Cycles appeared to be shorter than previously reported in this population and for other *Dipodomys* species. The median cycle length was 9.5 days (range 6-20; Figure 1). Mean individual cycle length for the six females ranged from 6.3 to 20 days. Mean cycle length was not positively correlated with cycle lengths obtained from these females by other researchers in previous months ( $R_s = -0.727$ ;  $N = 5$ , NS). This could be due to our inexperience in determining stage of estrus cycle or to seasonal variability. Measurement of estrous cycle length was also complicated by the tendency of several females to remain in a swollen, perforate state for prolonged periods. For example, three females remained swollen and perforate for 13, 16 and 17 consecutive days. These females returned to a state of apparent vaginal estrus (stage 3) without reaching a state of anestrus (stage 1).

### Urine collection

Females varied widely in the reliability of urine production. One female never urinated when placed in the tub, while five females urinated on every (or virtually every) attempt. Mean urine volume did not change with time ( $R_s = 0.026$ ; NS; Figure 2), nor did color ( $R_s = -0.129$ ; NS; Figure 3). This indicates that animals can be expected to produce urine of consistent quantity and concentration on a regular basis for long periods of time. This is important to know if attempts are to be made to monitor urinary hormones on a long term basis.

Females differed significantly in the amount of urine they produced ( $F = 17.53$ ;  $df = 7, 248$ ;  $p = 0.000$ , Figure 4) but a females's mean urine volume was uncorrelated with the reliability of urination ( $R_s = 0.274$ , NS). That is, females that were easily induced to urinate did not produce more or less urine than females that urinated less readily. Females also showed significant individual variation in urine color ( $X^2 = 106.6$ ;  $df = 14$ ;  $p = 0.000$ ; Table 1). This may indicate considerable individual variation in urine concentration or composition, which may be problematic for studies of urinary hormones.

### Urine Collection Protocol Evaluation

The experiment was conducted after one month of daily urine collection. Using the standard procedure, urine was collected from three groups of female *D. heermanni*: "trained" ( $N = 6$ ), "untrained" ( $N = 3$ ) and "naïve" ( $N = 3$ ). Trained females urinated on virtually 100% of attempts to collect urine (mean = 99.5% of attempts, range = 97-100%). Untrained females urinated at a much lower mean rate of 44% (range = 0-74%) of collection attempts. The naïve females had not previously been included in urine collection for this study, but may have had urine collected from them in 1991. Variables measured were (1) the time elapsed until the female urinated, (2) whether the female attempted to jump out of the urine collection bin prior to urinating, (3) whether the female had to be coaxed back into her nestbox

after urinating and (4) whether the female remained hidden inside her nestbox after being returned to her home cage. Urine volume and concentration (as estimated by color) was also recorded.

We hypothesized that trained females would provide urine more rapidly than either the untrained or naïve females. This did indeed appear to be the case (Figure 5). Due to sample size limitations, the untrained and naïve groups were combined for statistical analysis. Trained females urinated significantly sooner after being placed in the urine collection bin than did the untrained/naïve females ( $F=7.356$ ,  $df=10$ ,  $p=0.022$ ). Although trained females had the shortest mean latency to urinate, a female from the naïve group had the shortest latency over all (15 sec).

Urine volume did not differ among the treatment groups ( $t=-0.592$ ,  $df=9$ , NS) and there was no correlation between urine volume and the time elapsed to urination ( $R_s=-0.179$ , NS). A negative correlation might indicate that the animals that urinate most quickly are those whose bladder is most full. If true, this could call into question the interpretation of trained animals urinating most quickly.

An additional concern was whether the training regime would induce females to urinate even when their bladders were almost empty, resulting in too little urine for meaningful hormone analyses. We were also concerned that naïve and/or untrained females might produce too little urine for analysis. If this were the case, urine training procedures would have to be undertaken long before samples were desired for hormonal analysis. However, this proved not to be the case. Ten of the 11 females who urinated produced at least 100  $\mu$ l of urine, an adequate amount for hormone analyses.

Attempts to jump out of the urine collection bin were marginally more common among the untrained/naïve group (Figure 6, Fisher's exact test,  $p=0.061$ ). Trained females never attempted to escape, while 4 of 6 untrained/naïve females tried to jump out. This may be due in part to the greater time untrained/naïve females spent in the bin (because they took longer to urinate). Most females began to jump for the rim of the bin after 3 to 4 min in the bin, although one naïve female began jumping after only 5 sec. By the time 3 min had elapsed, the trained females had long since urinated and had been returned to their home cages. It is not known whether the trained females would have started attempting to jump out if they too had been left in the bins for more than 3 min.

Most (92%) of the females returned to their nestboxes after urinating without having to be coaxed or prodded (Figure 6). One naïve female continued trying to escape by jumping for the rim long after her nestbox had been placed inside the bin. She had to be prodded in the direction of her nestbox. After returning to their home cages, most (75%) of the females poked their heads out of their nestbox to look at the experimenters or left the nestbox entirely. The untrained and naïve females were slightly (but not significantly) more likely to remain hidden within the nestbox (Figure 6).

## Discussion

The urination procedure we followed seems to be an efficient and effective way of gathering urine from female kangaroo rats. The trained females urinated quickly and showed few signs of distress during the procedure (e.g. attempts to escape during the procedure or remaining hidden afterwards). Naïve individuals showed the greatest signs of distress, and untrained females most resembled naïve individuals. This was

somewhat surprising, since the untrained females were as familiar with the procedure as the trained females. A rather high percentage of females (33%) did not provide urine reliably, even after 30 days of training.

Training of female kangaroo rats to provide urine followed a simple operant conditioning paradigm: The first few times they were placed in the bin they experienced some stress, and if their bladder were full, they urinated. They were then immediately allowed to return to the safety of their nestbox and home cage, which served as positive reinforcement. After only a few sessions of conditioning, most female kangaroo rats associated being placed in the bin with urinating, and they urinated promptly. They appeared to experience very little stress, rarely tried to escape and typically approached the investigators with apparent curiosity after returning to their home cage.

### **Hormone analysis**

Three consecutive urine samples from each of two females (a total of six samples) were sent to Dr. Larry Tamarkin at Assay Research, Inc. to determine whether luteinizing hormone (LH, which is indicative of ovulation) was detectable. Levels of LH in these two females were within the expected range for rodents (female 110041 mean =  $8.7 + 4.5$  nanograms/ml; female 110289 mean =  $7.4 + 4.1$  nanograms/ml). Peak levels of LH in one female (110041) coincided with the presumed time of estrus based on external morphology, however because of the small number of samples analyzed it was difficult to determine whether the observed increase in LH was a random fluctuation or was indicative of a preovulatory hormone surge. To further investigate this possibility, all urine samples collected from female 110041 were forwarded to Assay Research for LH analysis. Analysis of these samples is currently underway. If results prove informative, urine from the remaining females will be analyzed ■

## Table and Figure Legends

**Table 1.** Individual variation in the color of urine specimens produced over a 34 day period by eight female kangaroo rats (*Dipodomys heermanni*). Females are arranged in order of increasing urine concentration, as estimated by color. Urine color was classified into four categories, on a scale of 0 (colorless) to 3 (dark yellow). Values in parentheses indicate row percentages. Female 109825 was a *D. h. morroensis*.

**Figure 1.** Estrus cycle length in days for 12 cycles obtained from 6 female *D. heermanni arenae*.

**Figure 2.** Mean volume of urine for eight female kangaroo rats over 40 days of urine collection.

**Figure 3.** Mean color of urine for eight female kangaroo rats over 40 days of urine collection. Urine was subjectively rated on a scale of 0 (colorless) to 3 (dark yellow).

**Figure 4.** Mean ( $\pm$ SE) volume of urine produced by eight female kangaroo rats during 34 consecutive days of urine collection. All females are *arenae* except for a single *D. h. morroensis* (female 109825).

**Figure 5.** Mean ( $\pm$ SE) of the time elapsed from placement in the urine collection bin until urination by three classes of female kangaroo rat. The bar on the far right represents the values for untrained and naïve females combined.

**Figure 6.** The percent of trained, untrained and naïve female kangaroo rats that attempted to jump out of the urine collection bin, were coaxed back into their nestboxes after urinating and who hid within their nestbox following their return to their home cage.

**Figure 7.** Collecting urine specimen with a pipette from a female in the urine collecting bin.

**Figure 8.** Female being returned to nestbox immediately after urinating.

Figure 1

Kangaroo Rat estrus cycle length, July 6–August 6, 1992

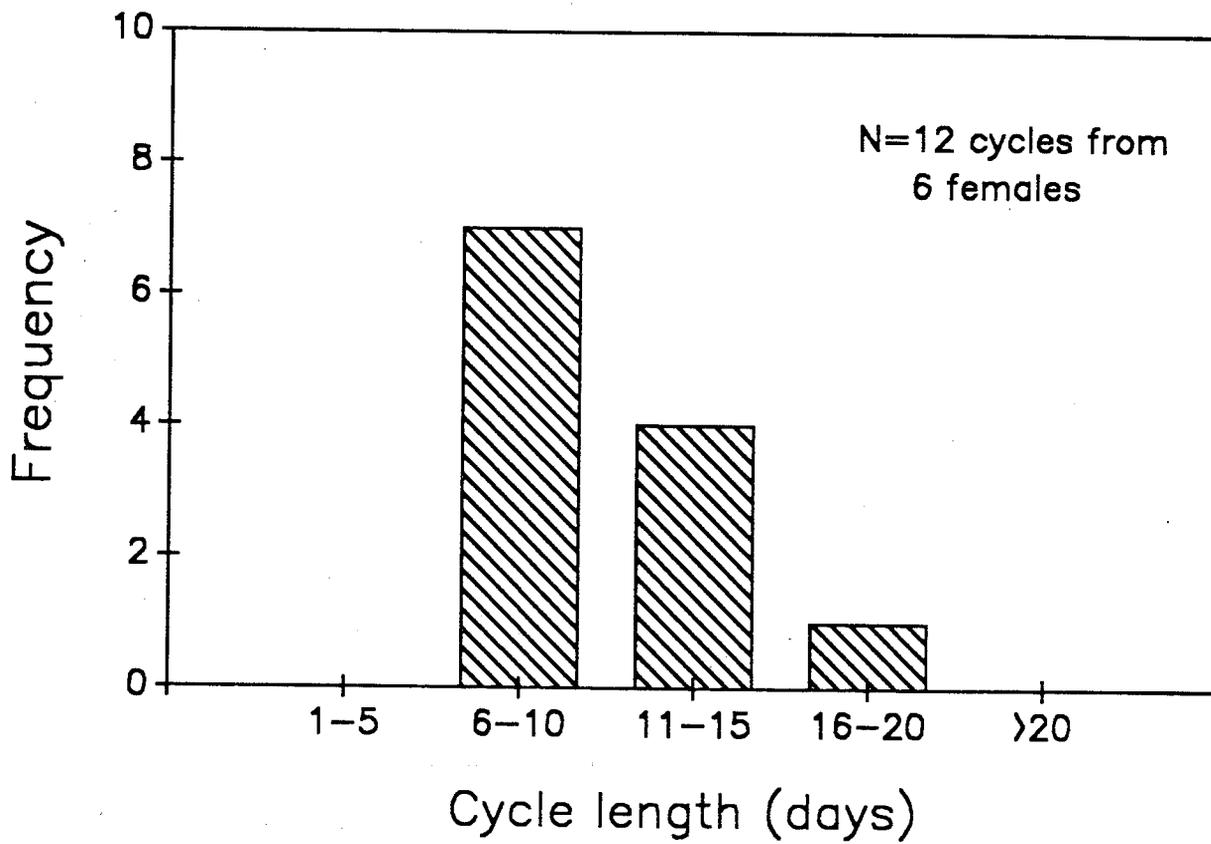


Figure 2

Mean volume of urine collected from eight female kangaroo rats during daily monitoring.

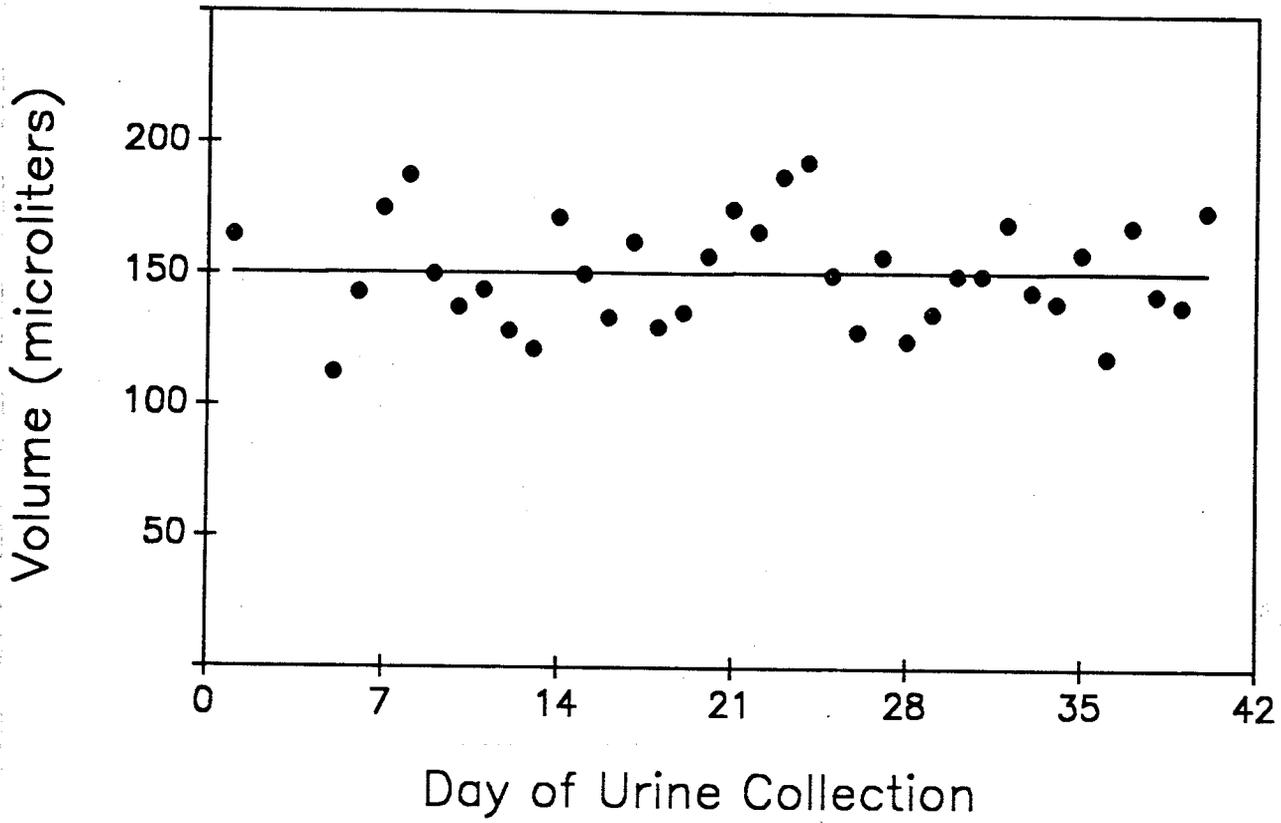


Figure 3

Mean urine color, measured on a scale of 0 (colorless) to 3 (dark yellow), of urine collected from 8 female kangaroo rats during daily monitoring.

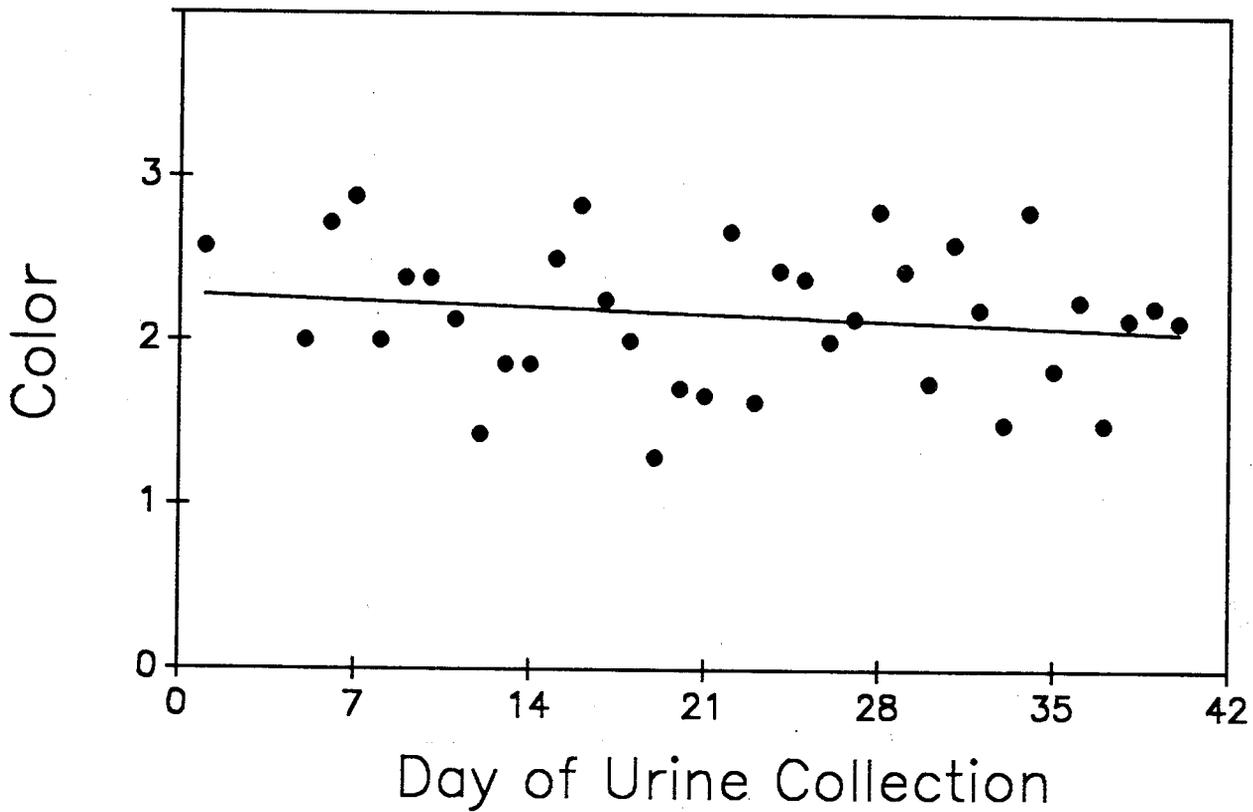


Figure 4

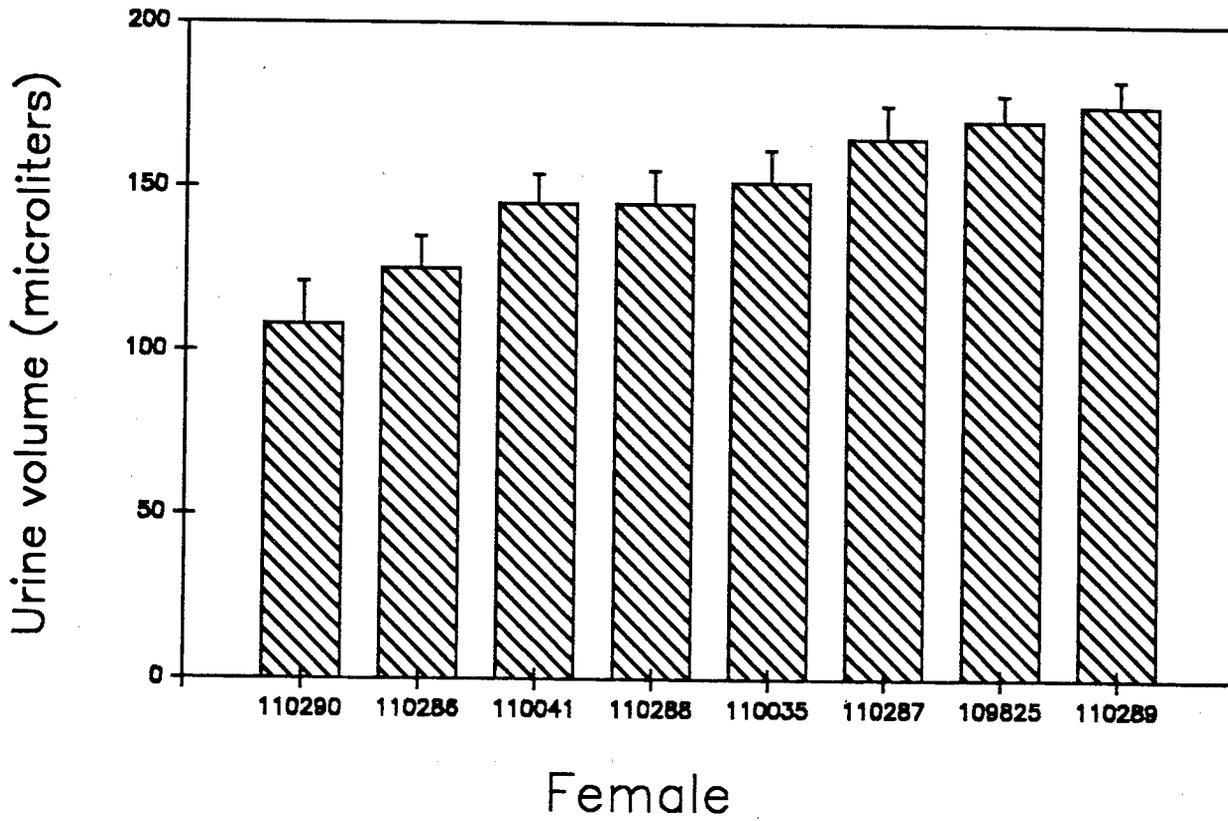


Figure 5

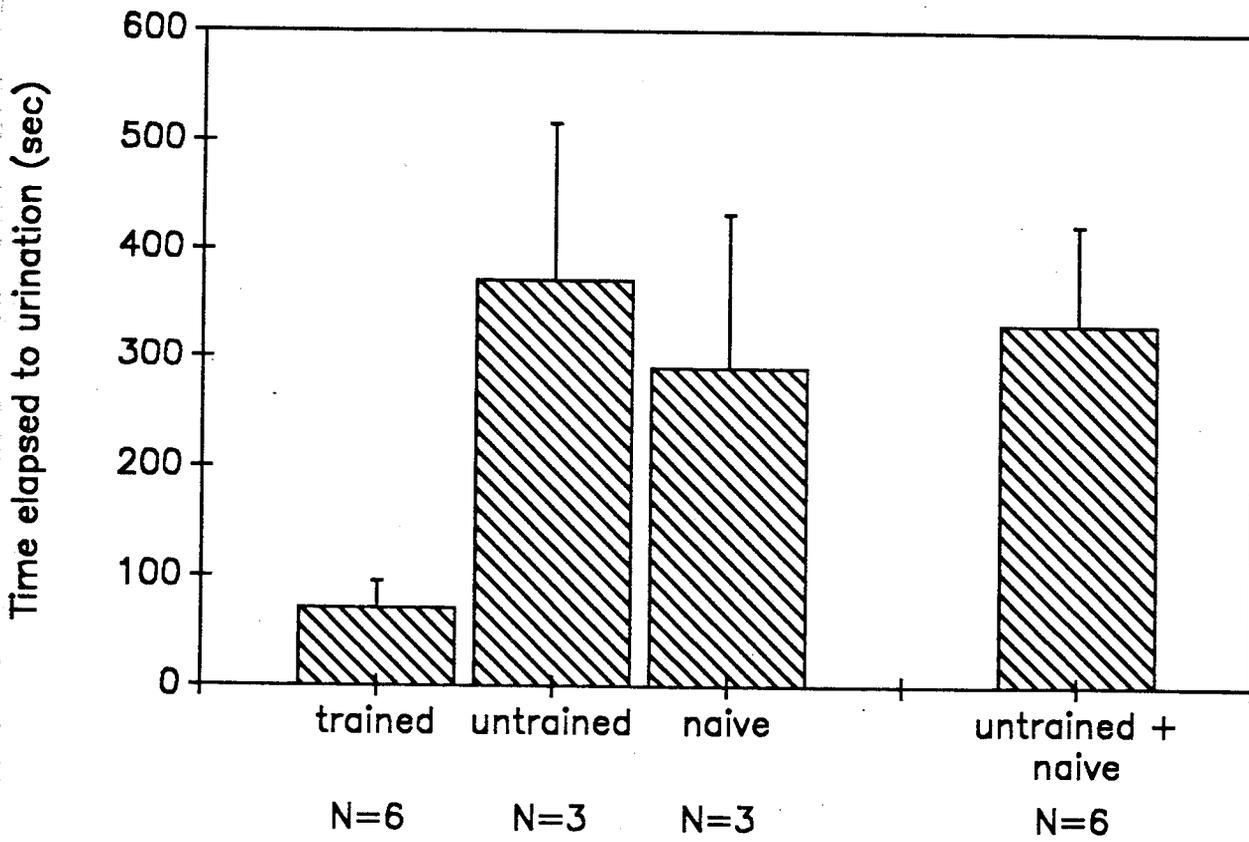
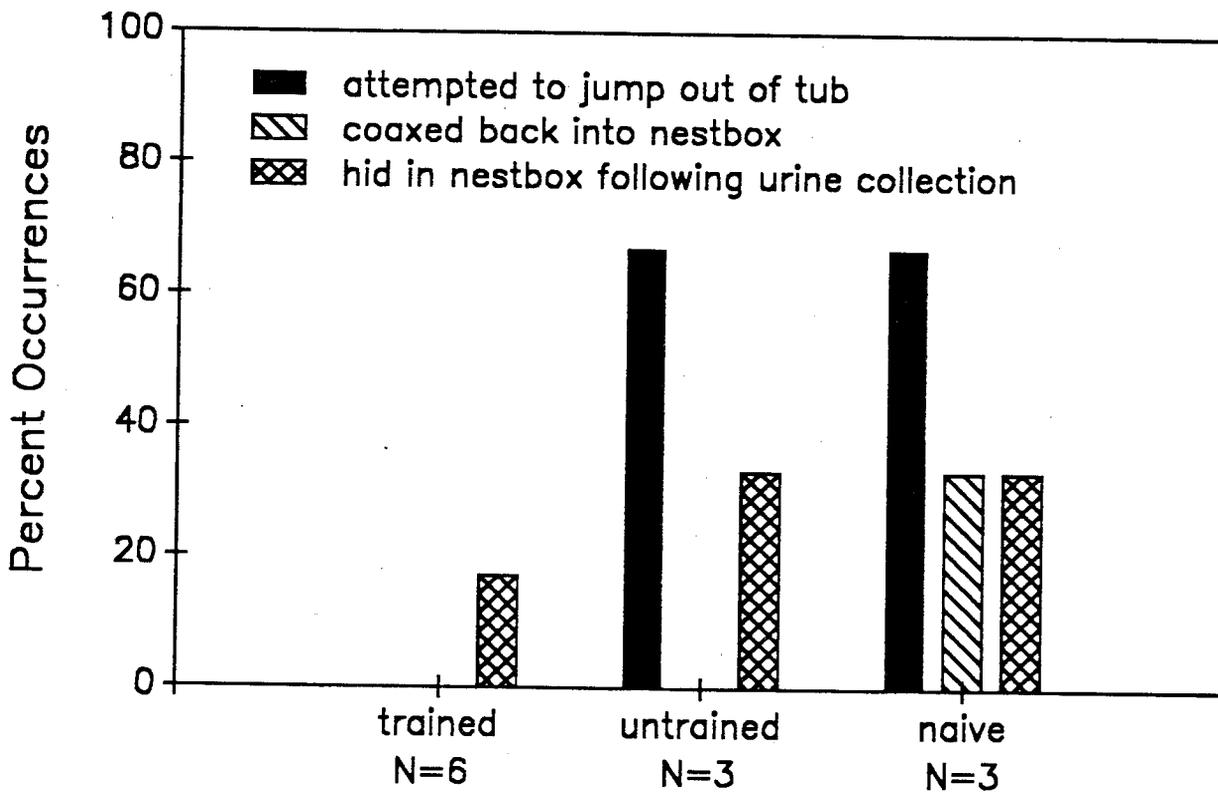


Figure 6





## Social Influences on Body Weight in Dipodomys heermanni

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Previous studies have shown a possible link between body condition and reproductive condition in female kangaroo rats, *Dipodomys heermanni* (Roberts and Rall, 1991). Body weight of captive kangaroo rats fluctuates seasonally, producing concomitant changes in body condition and, hence, the Condition Index (CI), estimated as the ratio of body weight to body length. Rate of estrus cycling in female kangaroo rats has been shown to vary with CI, with some females with low CI ceasing reproductive cycling. This suggests that heavy females (i.e. those with a higher CI) may be more likely to be reproductively active than light females (i.e. those with lower CIs).

Opportunistic observations also indicated that an individual kangaroo rat's weight may change dramatically depending on which of the two social conditions it was housed under (glass aquaria housing a single animal and a wooden cage complex in which adjacent animals could interact through a wire mesh screen). During experimental investigations of reproductive compatibility, kangaroo rats were occasionally moved between aquaria and the adjoining wooden cages. This provided an opportunity to examine the effects of housing condition (namely olfactory and tactile contact with individuals of opposite sex) on body weight (and CI).

### Methods

The subjects were 10 male and nine female Lompoc kangaroo rats (*Dipodomys heermanni arenae*) and one male and two female Morro Bay kangaroo rats (*D. h. morroensis*). All animals were initially housed individually in 25 x 50 cm aquaria. In January 1992, five female and two male *D. h. arenae* were placed into a system of wooden cages with wire mesh panels separating adjacent rats. Males were interspersed among the females. In October 1992 several of the kangaroo rats in the wooden cage system were removed to aquaria and two female and three male *D. h. arenae* were transferred from aquaria to the wooden cages. The transfer group consisted of a total of five males and seven females. Individuals of both subspecies continually housed in aquaria (six males and four females) served as a control group.

Body weights for all animals were routinely obtained at weekly intervals, and in some cases more frequently. Four consecutive body weights for each animal were obtained: two immediately preceding and two following the transfer. The first weight was obtained a mean of  $10.5 \pm 0.3$  days prior to transfer, the second  $1.5 \pm 0.3$  days prior, the third  $10.8 \pm 0.3$  days following the move and the final weight was obtained  $19.6 \pm 0.3$  days following transfer. For statistical comparison, weights for animals housed continuously in aquaria were obtained on the same days as for the rats transferred in January 1992. Weight changes were compared between the transferred group and the control group using a repeated measures analysis of variance.

## Results and Discussion

There was no overall difference in weight between males and females ( $F = 1.980$ ;  $df = 1,1$ ;  $p = 0.176$ ) or between the transferred and control groups ( $F = 0.765$ ;  $df = 1,18$ ;  $p = 0.393$ ). The interaction term was also not significant ( $F = 0.291$ ;  $df = 1,18$ ;  $p = 0.385$ ).

Within individuals, there was no overall effect of time ( $F = 1.841$ ;  $df = 3,54$ ;  $p = 0.151$ ) but there were significant interactions between time and sex ( $F = 6.014$ ;  $df = 3,54$ ;  $p = 0.005$ ) and time and treatment group ( $F = 8.922$ ;  $df = 3,54$ ;  $p = 0.001$ ). This indicates that the sexes differed in the manner in which weight changed over time, as did the treatment groups. Transferred males showed an initial decline followed by an abrupt increase in weight, while control males showed a steady decline (Figure 1). Females transferred into the wooden cages showed an abrupt increase in body weight following the transfer, while control females showed no obvious pattern (Figure 2). In general, transferred animals increased their body weights relative to control animals following their move.

A repeated measures analysis of variance was used to further characterize changes in weight separately for transferred males and females. For males, there was no significant increase in body weight over time ( $F = 2.011$ ;  $df = 3,12$ ;  $p = 0.166$ ). Females did show significant increases in weight ( $F = 11.786$ ;  $df = 3,18$ ;  $p = 0.000$ ). A comparison of individual weighings showed that the only significant change in weight occurred between the time an animal was transferred and the first weighing thereafter, approximately 10 days after the transfer ( $F = 14.008$ ;  $df = 1,6$ ;  $p = 0.010$ ).

Housing condition has measurable effects on body weight. Moving an animal from a solitary situation to one in which visual, olfactory, auditory and tactile communication with conspecifics was possible resulted in an increase in weight. These effects appear more pronounced in females, and occur within days of a change in housing. It is unlikely that the observed changes were due to differences in cage size or diet. The wooden cages were approximately the same size as the aquaria (1460 vs. 1250 cm<sup>2</sup>) and in all instances animals were fed the same diet before and after the transfer. Rather, it is likely that some aspect of increased social stimulation results in weight gain.

If body condition (the ratio of body weight to length) is indeed related to reproductive condition, as suggested by earlier studies (Roberts and Rall, 1991), then housing kangaroo rats in cages permitting social contact may increase the likelihood of successful reproduction. In females, a gain in body weight may represent more stored resources available for lactation. Increased body weight may have beneficial effects on both the likelihood that a female will come into estrus and her ability to successfully raise offspring ■

### Figure Legends

**Figure 1.** Effects of housing condition on body weights of male kangaroo rats (*Dipodomys heermanni*). The first and second weights were obtained a mean of 10.5 and 1.5 days prior to transferring several rats from aquaria to the wooden cage complex. The third and fourth weights were obtained a mean of 10.8 and 19.6 days following the transfer. The point of transfer is indicated by an arrow.

**Figure 2.** Effects of housing condition on body weights of female kangaroo rats (*Dipodomys heermanni*). The first and second weights were obtained a mean of 10.5 and 1.5 days prior to transferring several rats from aquaria to the wooden cage complex. The third and fourth weights were obtained a mean of 10.8 and 19.6 days following the transfer. The point of transfer is indicated by an arrow.

Figure 1

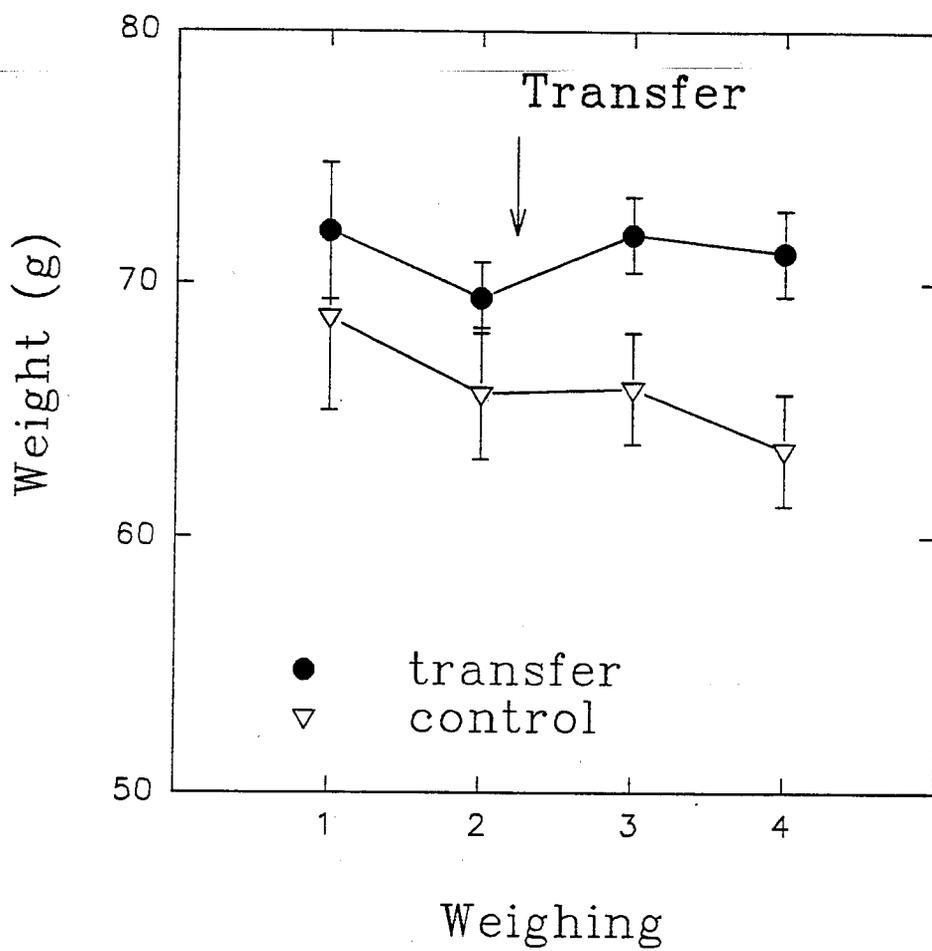
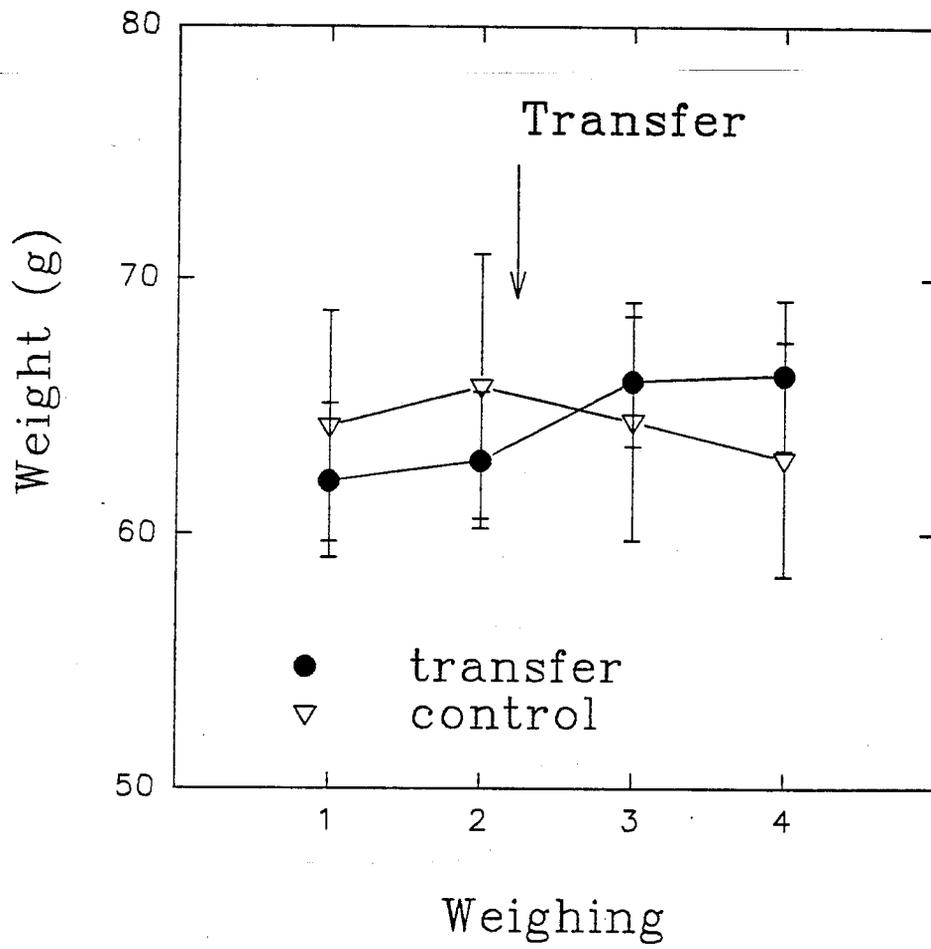


Figure 2



## Dyadic Encounters of Male and Female *Dipodomys heermanni*

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The breeding of kangaroo rats (genus *Dipodomys*) is problematic. When housed together, kangaroo rats often become highly aggressive; injury or death sometimes results (Roest 1988; Rathbun et al. 1990). Because of this extreme aggression, attempts to breed kangaroo rats have frequently used the technique of dyadic encounters (placing a male and female together in a small enclosure for a limited period of time under close supervision). This technique has been used in attempt to start breeding colonies of *D. h. arenae* and *D. h. morroensis* at the National Zoo. Even when the female appeared to be in vaginal estrus, aggression severe enough to necessitate separating the pair usually resulted and copulations occurred in only 5% of pairings (Roberts and Rall, 1991).

Several species of *Dipodomys* are critically endangered, and attempts are underway to identify methods of inducing them to breed in captivity, as a way of supplementing the diminishing natural populations. The following series of experiments was designed to examine the effect of familiarity, estrus condition and consistencies in male behavior on reproductive success in *D. heermanni*. Because of the limited number of Morro Bay kangaroo rats, *D. h. morroensis*, in captivity at NZP (2 males and 2 females at the onset of the study) and their advanced age (5 years), all experiments were conducted using a closely related surrogate, the Lompoc kangaroo rat, *D. h. arenae*.

### Effect of Familiarity on Behavior of Male and Female Kangaroo Rats (*Dipodomys heermanni*) During Dyadic Encounters.

Merriam's kangaroo rats (*D. merriami*) can discriminate neighbors from strangers and direct more affiliative behavior towards familiar individuals (Randall 1989, in press). Familiarity may be a critical factor in determining pair compatibility and eventual reproductive success, therefore we attempted to assess the effect of familiarity on behavior of male and female kangaroo rats (*D. h. arenae*) during dyadic encounters.

### Methods

Subjects were 9 female and 5 male *D. heermanni arenae*. All females were judged to be anestrus based on the absence of swelling of the external genitalia and an imperforate vagina. Females were tested with either a familiar male (N=4) or with a stranger (N=5). Familiar males were those who had been housed in 28 cm x 52 cm cages adjacent to one or more females, separated by a 18 cm x 34 cm wire mesh panel. The mesh was large enough to permit some tactile contact between neighbors, as well as visual and olfactory contact. This housing arrangement was maintained for an 8 month period prior to the onset of testing. One additional male and female included in the familiar group had shared a 3.3 m x 5.1 m room for a period of 6 months prior to testing. Strangers males were defined as males with which a female had no prior contact during the previous 6 months. In all cases, stranger male were housed in separate rooms

from the females they were tested with. Each female was tested once. Because of the limited number of animals available and the limitations of the cages used to allow familiarity, males were occasionally tested against more than one female. One male was used three times (twice as a familiar male and once as a stranger) and one male was used once in each trial type.

Observations were conducted during the dark phase of the light cycle, approximately 1 hour after the onset of darkness. Encounters were staged in a circular, neutral arena 1 m in diameter and 1 m high. A layer of clean sand 1-2 cm in depth was used as a substrate. The arena was illuminated by a blue, 40 watt light bulb suspended overhead. For each encounter, the female was placed first into the arena, and the male was introduced within 30 seconds. Animals were allowed to interact freely for 5 minutes. This time period was chosen because it was common for encounters to escalate quickly into damaging aggression. In order to prevent injury to the subjects and to ensure a consistent trial duration for statistical comparisons, animals were separated after 5 minutes. In pairs allowed to interact for more than 5 minutes, those that showed high levels of aggression in the first few minutes continued to behave aggressively throughout the encounter, while those that were affiliative generally remained that way. Thus the first 5 minutes of an encounter was judged to be representative of the compatibility of a pair.

To facilitate comparison with similar studies of *D. merriami*, behaviors recorded during encounters were the same as recorded by Randall (in press). The behaviors recorded were:

- (1) Approach - a movement by one rat which decreases the distance between the two rats.
- (2) Depart - a movement to increase the distance between two rats.
- (3) Attack - any aggression including hind leg kicks, attack leaping, lunges, grappling and biting.
- (5) Contact - any non-agonistic physical contact between two rats including naso-nasal or naso-anal sniffing, mounting and crawling over another rat.

Approach and Depart frequencies were calculated for each individual. For Attack and Contact both frequencies and durations were calculated. In practice it was often difficult to determine the initiator of Attacks and Contact. For these variables, values were summed across the male and female to produce a single score for each trial. Behavioral frequencies and durations were compared between groups with a Mann-Whitney U test.

## Results and Discussion

Mean values for eight behavioral measures are shown in Figure 1. Strangers fought significantly more often and for longer durations than familiar pairs ( $U=0$ ,  $N=9$ ,  $p=0.02$  for both Attack frequency and duration). Attacks occurred in 25% of encounters between familiar animals and 100% of encounters between strangers. Familiar pairs showed a tendency to have more Contact, but not significantly so.

These results are strikingly different from Randall's (1989, in press) findings for *D. merriami*. In her studies, familiarity among males and females resulted in increased Contact, but no difference in Attack rates or duration. Attacks were reported in only 12% of staged encounters between neighbors and 25% of encounters between strangers.

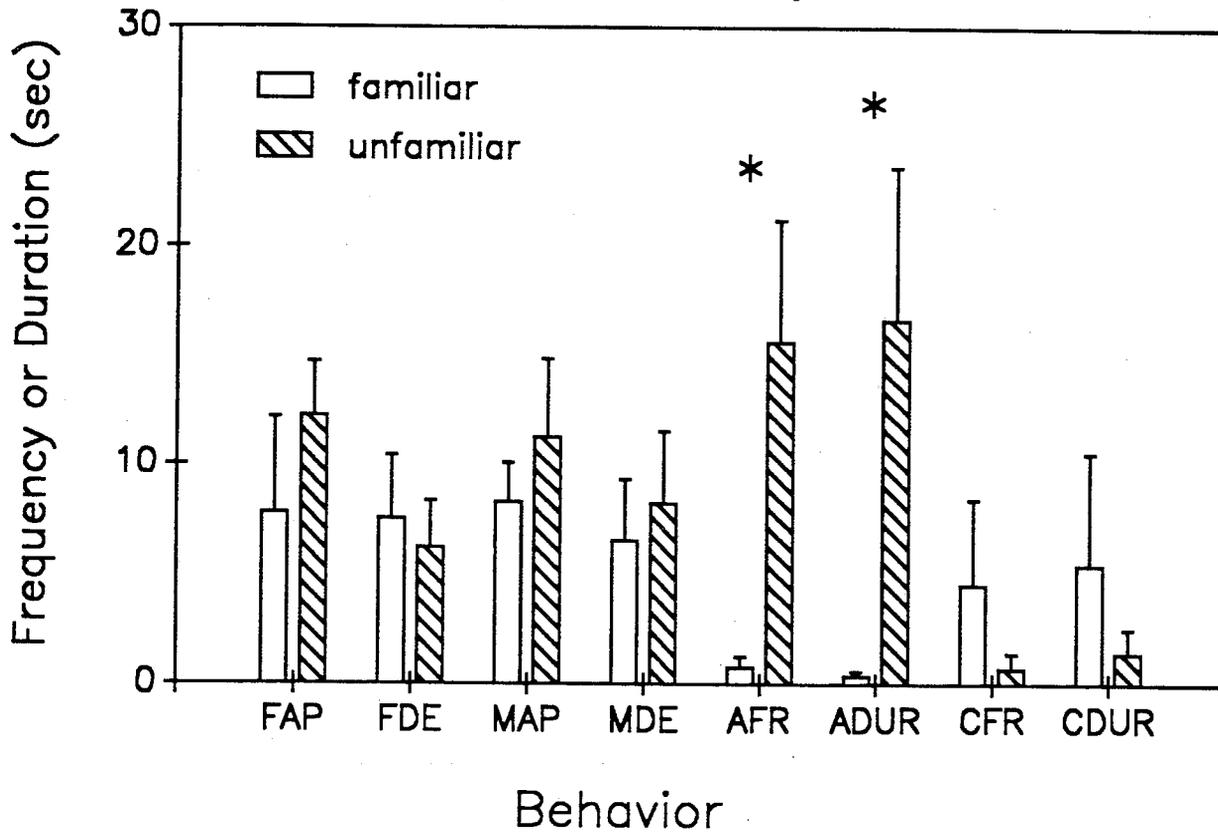
Discrepancies between the studies may reflect differences in methodology, the individual life histories of the subject animals or interspecific differences in social organization. Randall's encounters were staged in slightly larger arenas (1.2 and 1.9 m in diameter). Smaller arenas may force animals to interact more often by decreasing their ability to avoid each other. However, interaction rates of Randall's subjects did not appear to be affected by arena size. Randall's subjects were free-ranging and tested in the field. The rats used in this study have been maintained in captivity for 1 year or more. The effect of longterm captivity on social behavior is unknown, but is conceivably dramatic. Many factors remain to be investigated, however it is clear that familiarity has a profound influence on the nature of social interactions among male and female *D. heermanni* in captivity ■

### Figure Legends

**Figure 1.** Behavior during 5-minute paired encounters between anestrus female kangaroo rats (*Dipodomys heermanni arenae*) and familiar and unfamiliar males. Values marked with an asterisk were significantly different at the  $p = 0.02$  level by a Mann-Whitney U test. FAP = female approach, FDE = female depart, MAP = male approach, MDE = male depart, AFR = attack frequency, ADUR = attack duration, CFR = contact frequency, CDUR = contact duration.

Figure 1

Behavior during 5-minute paired encounters between anestrus female kangaroo rats and familiar and unfamiliar males. Values marked with an asterisk were significantly different at the  $P=0.02$  level by a Mann-Whitney U test.



**Effect of Familiarity on Behavior During Dyadic Encounters  
Between Male and Hormone Treated Female  
Dipodomys heermanni.**

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All previous experimental investigations of behavior during paired encounters have utilized anestrus females (Randall 1989; in press). Randall (in press) has suggested that although anestrus females behave more affiliatively and less aggressively towards familiar males, they are indiscriminate during estrus. If so, then careful selection of females that are in peak estrus should be sufficient to allow mating in captivity without any special consideration to housing modifications or previous social experience. If, however, female preferences for familiar males persist during estrus, then housing situations allowing contact between males and females will be necessary to promote captive breeding.

If familiarity affects the outcome of encounters between males and estrous females, then several additional factors need to be examined in order to devise appropriate breeding protocols. First, is sufficient familiarity achieved on a time scale of days, weeks or perhaps months? Second, does familiarity inevitably promote compatibility or are other factors also involved?

**Methods**

Subjects were six female and seven male kangaroo rats, *Dipodomys heermanni arenae*. Because of the difficulty pinpointing behavioral estrus, we attempted to induce receptivity by administering exogenous hormones. Anestrus females were given 0.01 mg of estrogen subcutaneously for two consecutive days. Injections were given during the light phase of the circadian cycle, approximately three hours prior to the onset of darkness. Beginning the day of the first injection and for four days following each female was tested with a familiar male (residing in an adjacent cage separated by a wire mesh panel) and an unfamiliar male (residing at least three cages away in the wooden cage complex or housed solitarily in another room). The order in which each female encountered a familiar and unfamiliar male was counterbalanced across females and across days. Each female was tested repeatedly against the same familiar and unfamiliar male throughout the five days of testing, allowing evaluation of the effect of short term repeated encounters on behavior. Four of the males were tested in both roles (familiar and unfamiliar), one was used only as a familiar male and two were used as unfamiliar males.

All behavioral observations were conducted during the dark phase of the light cycle, one to two hours after the onset of darkness. During dyadic encounters, a female was placed in a cylindrical arena 1 m in diameter with 2 cm of clean sand as substrate. A single male was introduced to the arena within 30 seconds. Recording of behaviors commenced with the introduction of the male and continued for 15 minutes. Behaviors recorded are described in the previous section. Encounters on the same day using the same female were spaced at least 30 minutes apart to minimize carry-over effects from

As for the previous study, behavioral frequencies were determined for males and females separately for Approach and Depart, and jointly for each pair for Attack frequency and duration and Contact frequency and duration. Behavioral differences between the familiar and unfamiliar conditions and changes in behavior over time were evaluated with a repeated measures analysis of variance.

## Results

### Hormone Administration

All females showed an increase in vulval swelling and became perforate during the course of observations, but only one female came into estrus (as judged by vulval swelling and behavior). The remaining females reached the peak of vulval swelling two to seven days following the completion of observations.

### Copulations

The female which came into vaginal and behavioral estrus during the course of observations was the only one to copulate. She mated twice with the familiar male but never mated with the unfamiliar male (even though she interacted with him on the same days as she mated with the other male). The first mating occurred on the second day of observation (the day of the second estrogen injection) and the second mating occurred on the fourth day of observation. Both matings occurred after the 15-minute observation session had ended. During each encounter resulting in copulation it became obvious that the female was in behavioral estrus but the male was unable to mount for long enough to achieve intromission. Mating occurred when the pair was confined to a 8 x 10 x 24 cm wooden nestbox, a technique that had been used with success previously (Roberts and Rall 1991).

### Effect of familiarity

Familiarity had no significant effect on the frequency of Approaches and Departs by both males and females (Figures 1-4). Contact frequency and duration was significantly greater among familiar pairs than among unfamiliar pairs ( $F = 20.940$ ;  $df = 1,5$ ;  $p = 0.011$  and  $F = 22.247$ ,  $df = 1,5$ ;  $p = 0.011$  respectively). Attack frequency and duration showed a trend in the direction of more aggression among unfamiliar pairs, but this was not statistically significant ( $F = 3.488$ ;  $df = 1,5$ ;  $p = 0.121$  and  $F = 3.566$ ;  $df = 1,5$ ;  $p = 0.118$  respectively).

There was significant individual variation among the pairs in Contact and Attacks, however. One female showed unusually high levels of aggression towards the familiar male that she was paired with (Figures 5C and 6C), suggesting pair incompatibility. When this female was removed from the data set, the effect of familiarity on Contact frequency ( $F = 66.271$ ;  $df = 1,4$ ;  $p = 0.001$ ) and duration ( $F = 45.656$ ;  $df = 1,4$ ;  $p = 0.003$ ) became even more pronounced. In addition a statistically significant difference in Attack frequency ( $F = 7.286$ ;  $df = 1,4$ ;  $p = 0.05$ ) and duration ( $F = 9.487$ ;  $df = 1,4$ ;  $p = 0.037$ ) became apparent. There was more aggression among unfamiliar pairs than familiar pairs.

The female that exhibited behavioral estrus differed from the remaining females in that she showed little or no aggression in her encounters with both the familiar and unfamiliar male (Figures 5B and 6B). Additionally, levels of contact with her familiar male were extremely high on the days of copulation (Figures 7B and 8B). The remaining four females were fairly consistent in their behavior. When both aberrant females were removed from the data set, differences in attack frequency and duration and contact frequency and duration remained statistically significant. Individual variation in attacks and contact are graphically depicted in Figures 5-8.

### **Behavioral changes over time**

Only one behavior showed statistically significant changes over the course of the five trials. Both familiar and unfamiliar males approached females more frequently with each successive encounter ( $F = 4.192$ ;  $df = 4,20$ ;  $p = 0.013$ ). There was no evidence that female aggression towards unfamiliar males lessened or their tolerance increased over the five successive trials. This suggests that a few days of repeated exposure are insufficient to establish familiarity. Longer periods of exposure may be necessary to cause a change in female behavior towards new males. Another possibility is that an initial aggressive encounter with a new male results in a long lasting aversion to that individual. In this experiment, familiar pairs were created by housing them on opposite sides of a wire mesh screen. The screen prevented them from any agonistic interactions during the weeks time preceding their first encounter. It is possible that females need a period of exposure to visual, auditory and or olfactory cues prior to any physical contact with a given male.

### **Behavioral indicators of estrus**

By comparing behaviors observed during encounters that resulted in copulation (termed estrus encounters) it may be possible to evaluate the receptivity of females and the probability that a pair will successfully breed. The estrus encounters were characterized by extremely high levels of male Approaches (consistent with the male persistence described by Daly et al. 1984), and levels of Contact an order of magnitude or more above baseline levels (Figures 6B and 6C). There was also an apparent suppression of female aggression towards the unfamiliar male. Levels of aggression between the familiar pair were surprisingly high, however, during estrus encounters (Figure 5B and 6B). Most aggression consisted of the male approaching the female from the front and batting her face with a forepaw. It appeared that males were attempted to provoke an aggressive response from the females in order to gauge their degree of receptivity. In an anestrus female, such behavior on the part of the male would likely result in an Attack by the female.

## **Discussion**

Familiarity indeed appears to be a critical factor in pair compatibility, but familiarity alone does not guarantee that a given pair will show behavioral tolerance. I suggest the following strategy for establishing successful pairs. Males and females should be allowed to live side by side in a situation similar to the wooden caging complex. After several weeks of such indirect exposure, potential pairs should be screened for compatibility. Incompatibility should be evident within five minute of introduction. Compatible pairs may then be released into large enclosures permitting continuous access but allowing each animal to escape unwanted interaction. An alternative strategy is to monitor the reproductive condition of females on a daily basis and to allow compatible

pairs to interact on a daily basis during periods of apparent estrus. The first strategy requires a great deal of space, but allows the animals unrestricted access to each other during periods of female receptivity. The second method is labor intensive and does not ensure that pairs will have access to each other when the female is ready to copulate

### Figure Legends

**Figure 1.** The frequency with which familiar and unfamiliar males Approached females during paired-encounters on five successive days.

**Figure 2.** The frequency with which familiar and unfamiliar males Departed from females.

**Figure 3.** The frequency with which females Approached familiar and unfamiliar males.

**Figure 4.** The frequency with which females Departed from familiar and unfamiliar males.

**Figure 5.** The frequency of aggressive Attacks during encounters between familiar and unfamiliar pairs of kangaroo rats. (A) Compatible familiar pairs, female not in behavioral estrus. (B) Compatible familiar pair, female in behavioral estrus during trials 2 and 4. (C) Incompatible familiar pair.

**Figure 6.** The total Attack duration during encounters between familiar and unfamiliar pairs. The sample was divided into three subsets as described above.

**Figure 7.** Contact frequency for familiar and unfamiliar pairs of kangaroo rats. The sample was divided into three subsets as described above.

**Figure 8.** Total Contact duration for familiar and unfamiliar pairs of kangaroo rats. The sample was divided into three subsets as described above.

Figure 1

### Male Approach

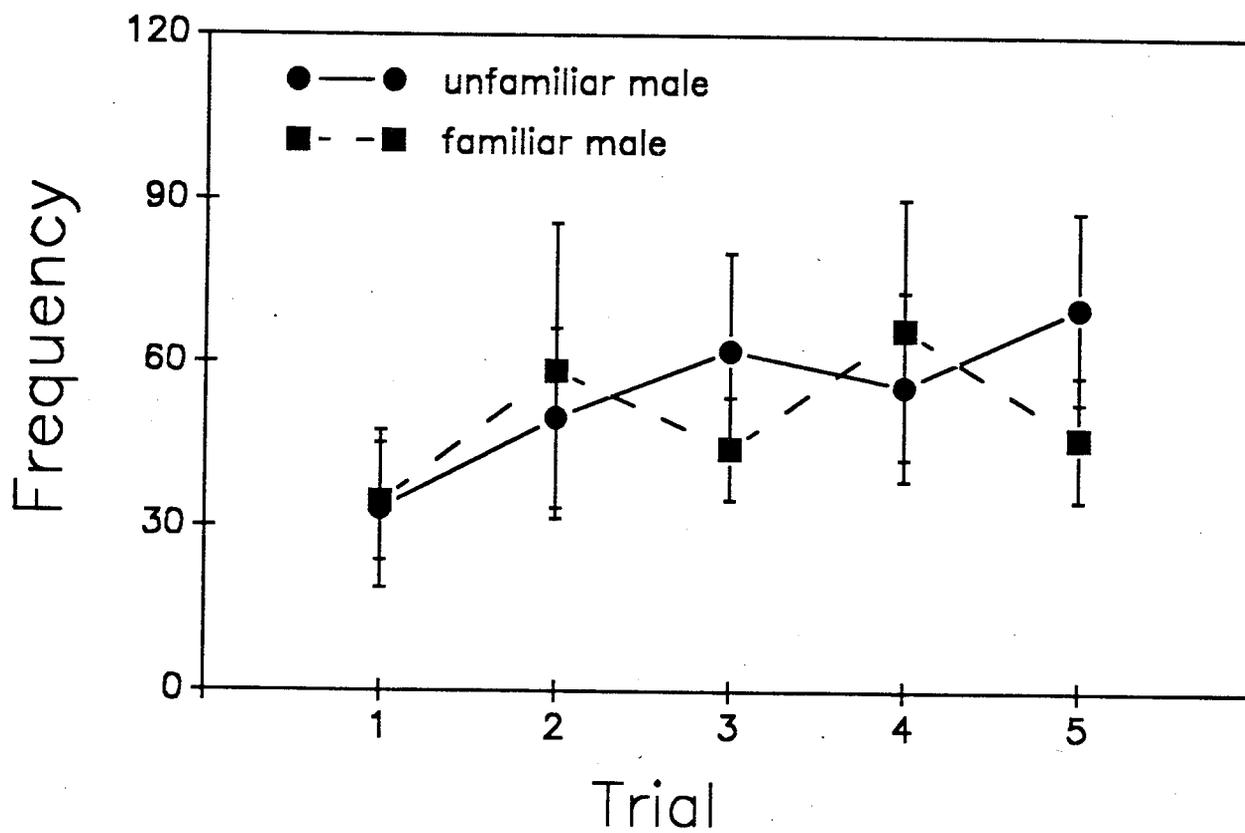


Figure 2

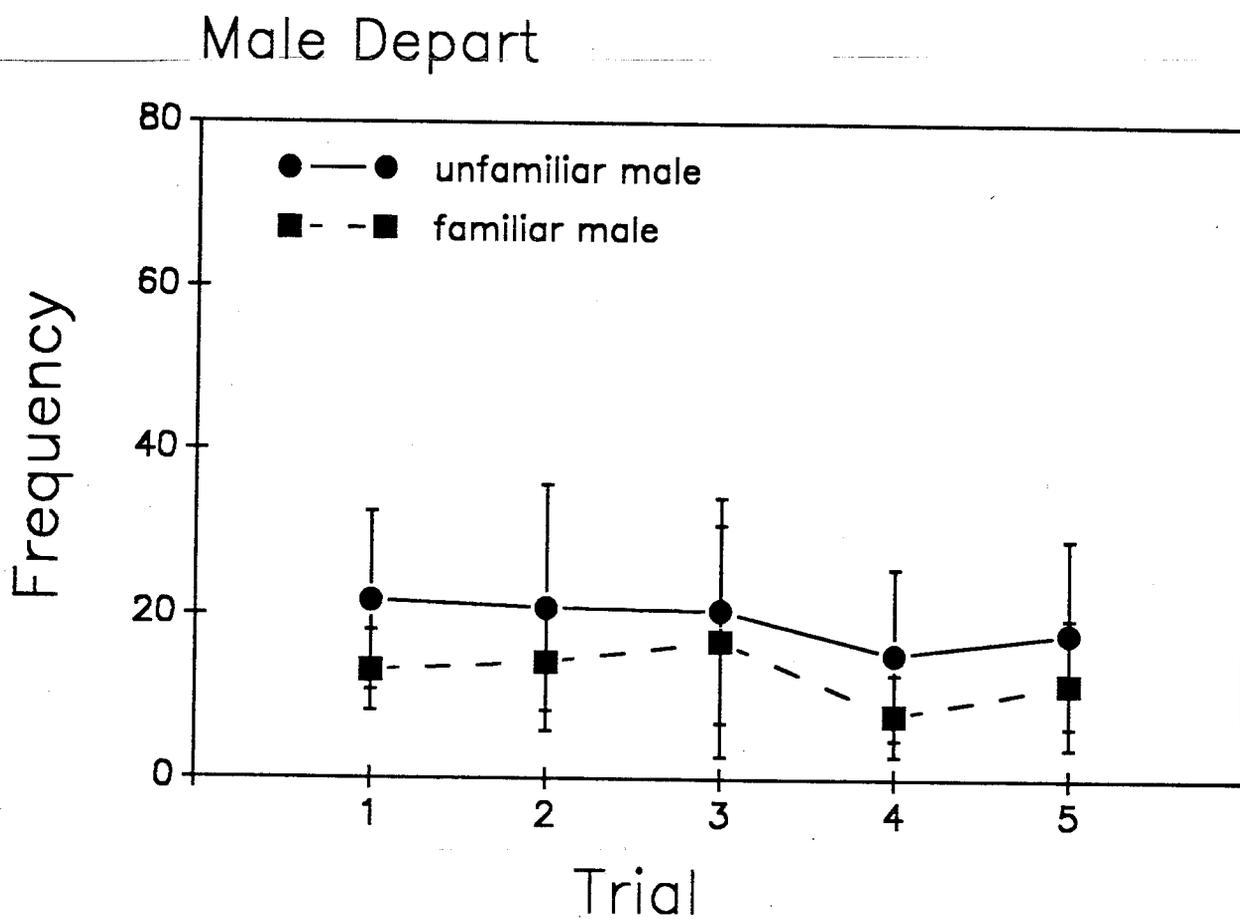


Figure 3

### Female Approach

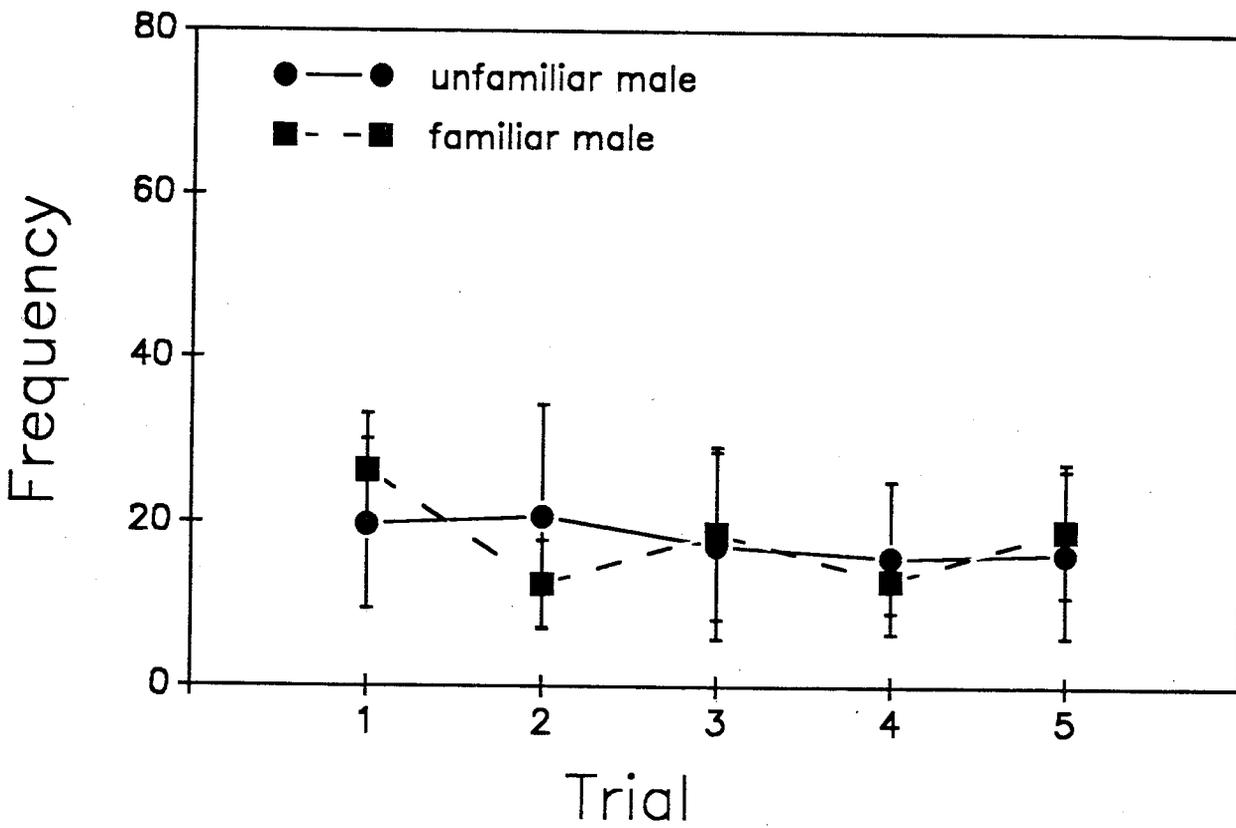
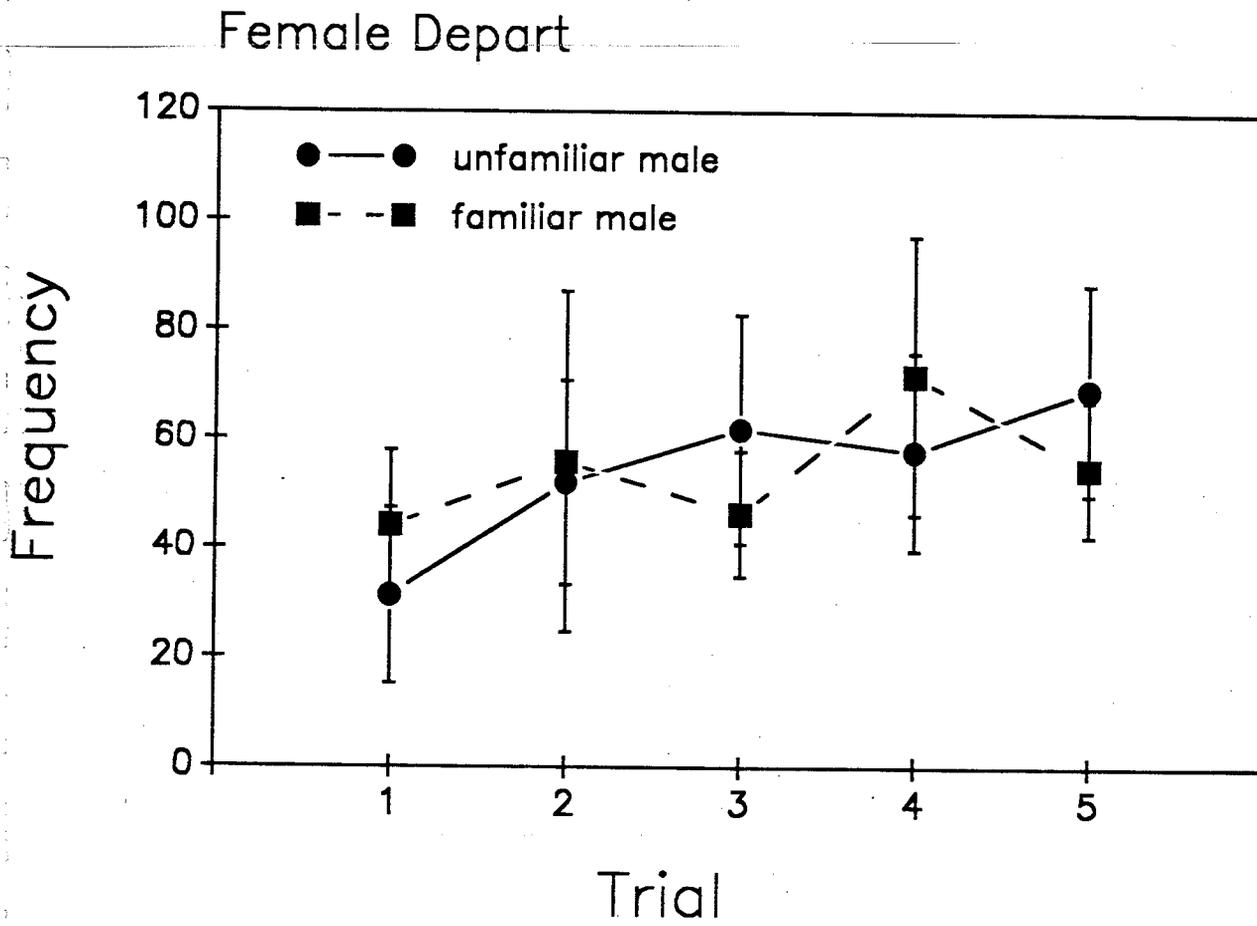
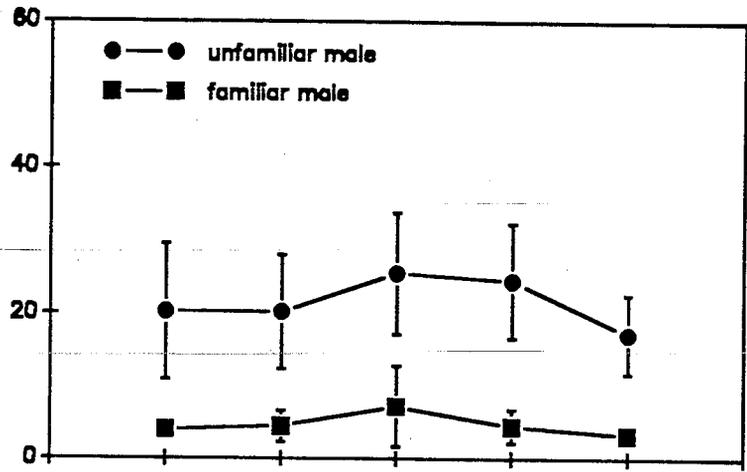


Figure 4

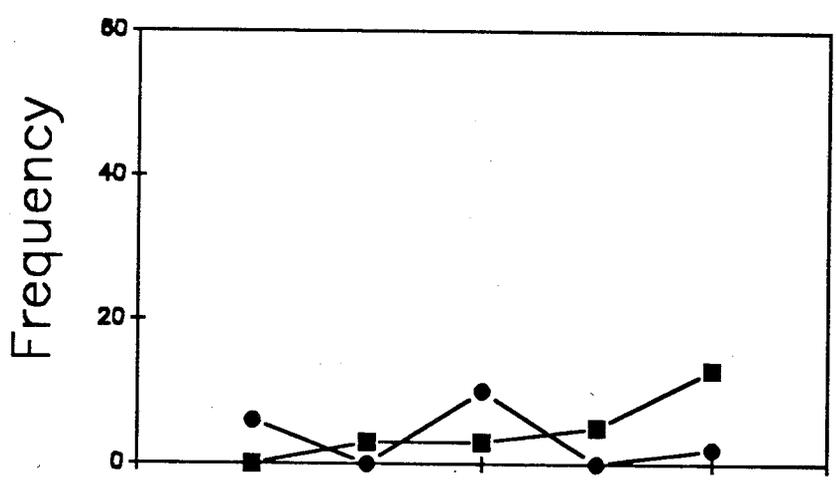


### Frequency of Attacks

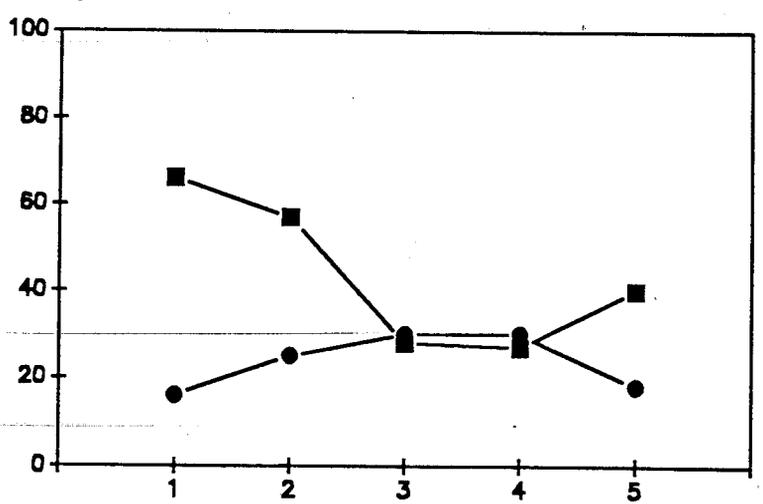
A)



B)



C)



Trial

Figure 6

Duration of Attacks

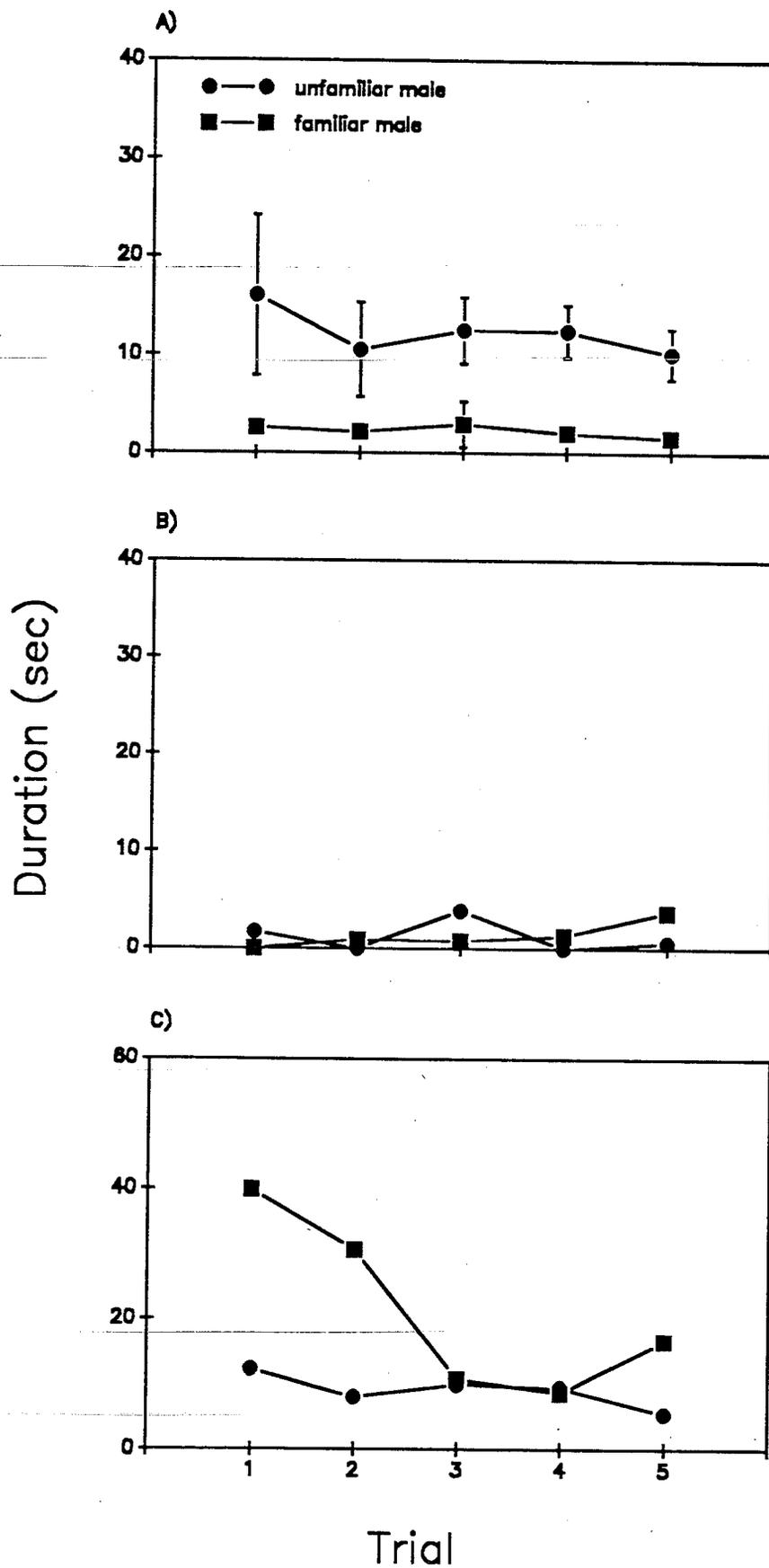


Figure 7

Frequency of Contact

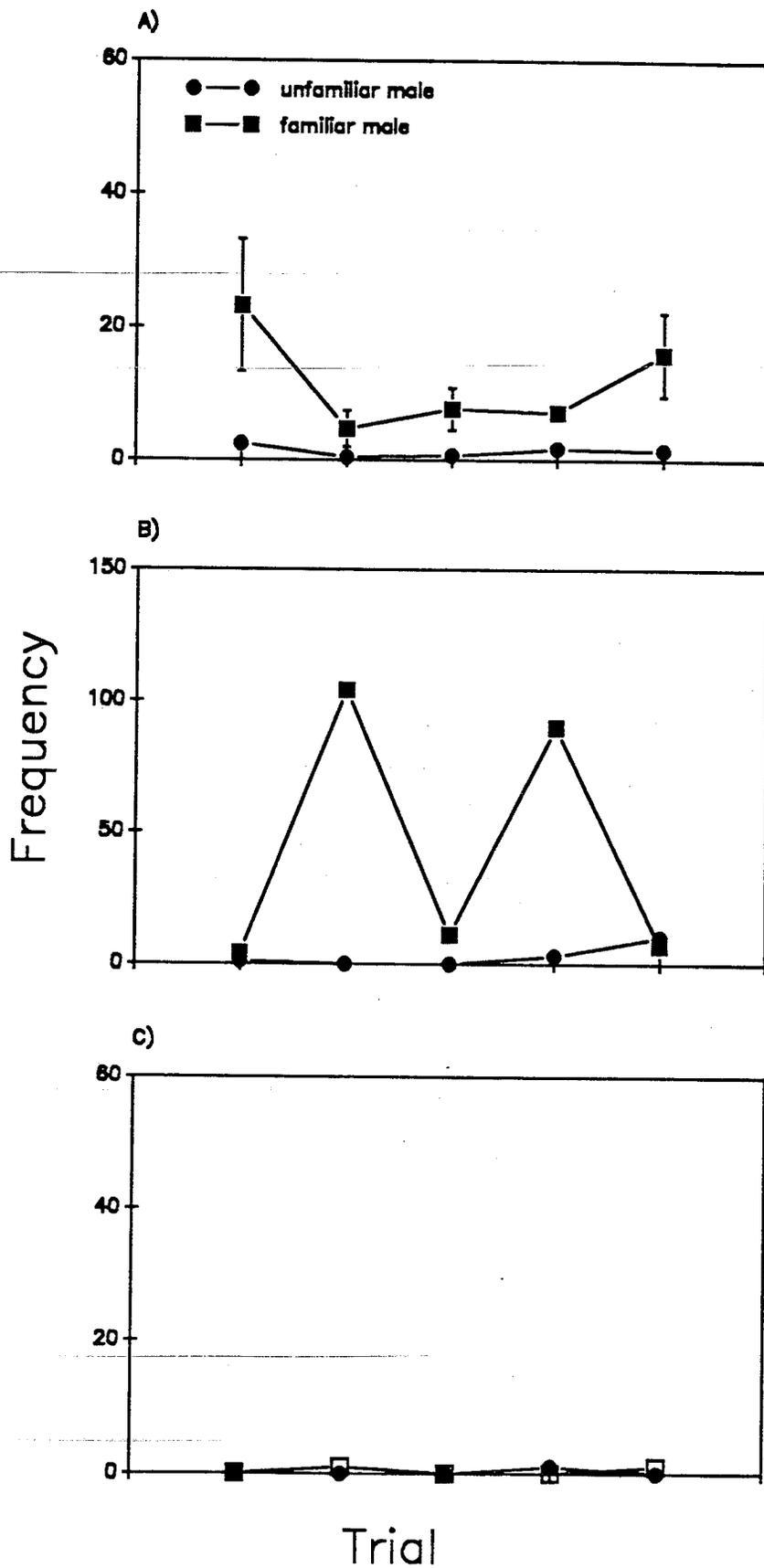
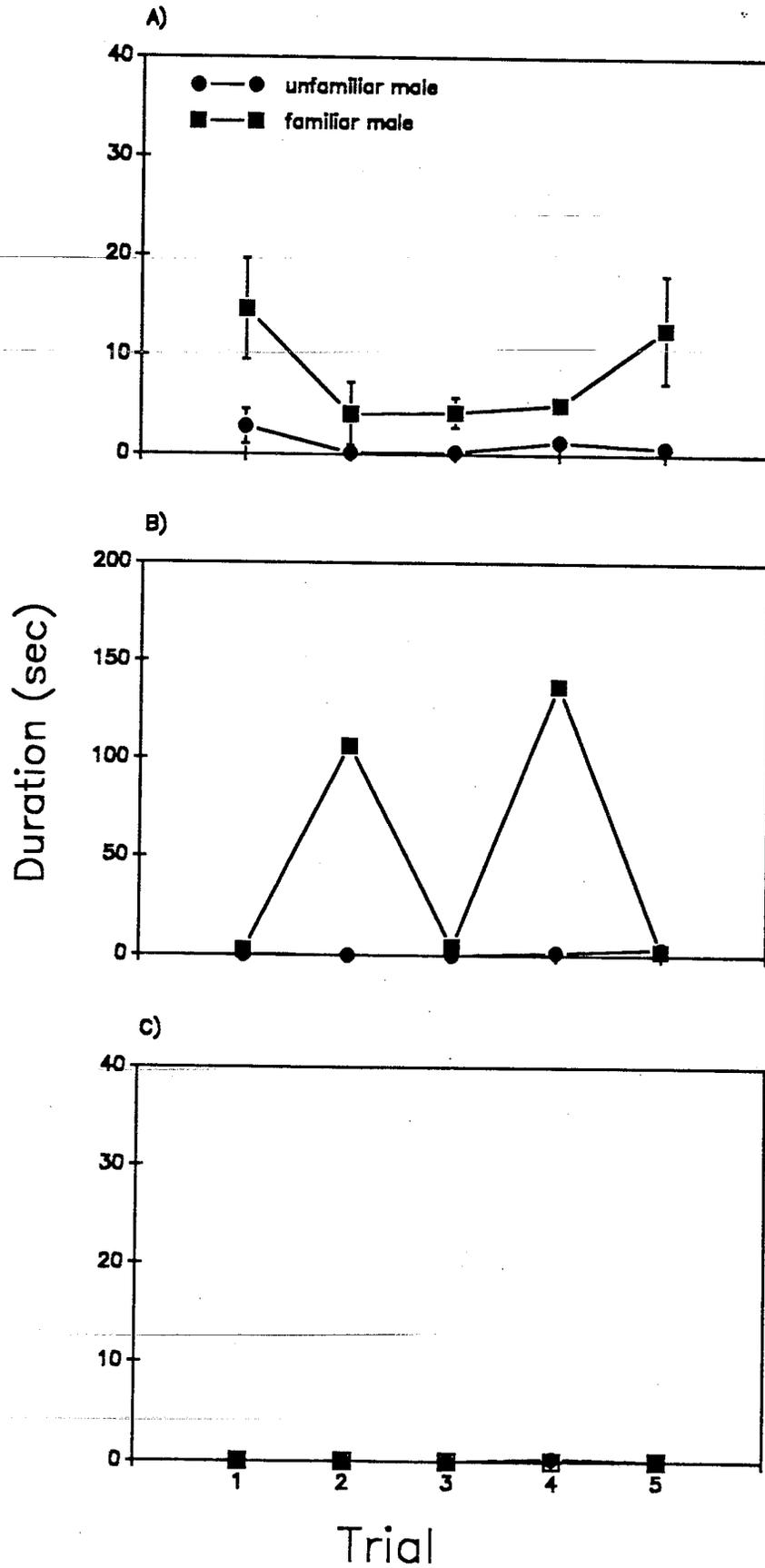


Figure 8

Contact Duration



## Behavioral Strategies of Male Dipodomys heermanni arenae During Encounters with Anestrous Females

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Attempts to establish breeding colonies of kangaroo rats (*Dipodomys spp.*) have met with little success (Day et al., 1956; Butterworth, 1961; Daly et al., 1984; Rathbun et al., 1989, 1990; Roest, 1991). Lack of breeding competence has been reported for both sexes, but is especially pronounced in males. Only a subset of apparently sexually mature individuals actually copulate and produce offspring. Daly et al. (1984) were successful in establishing a captive colony of *D. merriami*, but only 10 of several dozen males were able to sire offspring. Roest (1991) attempted to breed *D. heermanni arenae* and *D. h. morroensis* in captivity but had only sporadic success. Three of 15 *D. h. morroensis* males and four of 16 *D. h. arenae* males successfully bred. In previous attempts to breed *D. heermanni* at the NZP (Roberts and Rall 1991, colony records), only two of 18 males copulated and no litters were produced. In all colonies, it was common for sexually mature males with descended testes to exhibit little or no interest in females who were likely in estrus.

The factors determining male reproductive competence are unknown. No obvious physical differences (e.g. degree of testicular development) existed among males that bred and those that failed to breed (Daly et al., 1984, Roest, 1991). Daly et al. (1984) noted that successful breeders were persistent in interacting with females regardless of the females' receptivity. The objective of this study was to determine whether the behavior of individual male kangaroo rats differed in predictable ways and to evaluate whether differences in behavior could be used to predict reproductive success.

### Methods

The behavior of four male and eight female Lompoc kangaroo rats, *D. h. arenae*, was evaluated in dyadic encounters. Each male was paired with six unfamiliar females on separate occasions for a total of 24 dyadic encounters. No animal was used more than once on any given day. Pairings were determined round-robin style, but because of the constraints of the housing conditions (e.g. some males and females were neighbors and were able to interact through wire mesh panels) not all males were paired with all females. Because of the difficulty in accurately determining estrus and to facilitate comparison with other studies, only anestrous females were used.

Experimental protocols, arena dimensions and behaviors recorded were the same as previously described in Chapter 2. Data from unfamiliar pairs in the study described in Chapter 2 were included in the following analyses as appropriate. Consistency in behavior was evaluated with analyses of variance, with male identity as the main effect. For ease of interpretation, principal components analysis was then used to reduce the eight recorded variables into a smaller number of components.

## Results and Discussion

Consistent behavioral differences among males were readily apparent (Table 1). Males differed significantly in the frequency with which they Approached females and the frequency with which females avoided them (Departed). They also differed in the frequency and duration of Attacks. Using principal components analysis, three components explaining 90.2% of the total variance were identified (Table 2). The first component was positively associated with male Approaches, female Departs and Attack frequency and duration and was negatively associated with female Approaches and male Departs. This component was interpreted as male dominance. The second component was highly associated with Attack frequency and duration and negatively associated with Contact frequency and duration. It was interpreted as aggression. The third component, which was highly associated with female approaches and male Departs, was interpreted as female dominance. Analyses of variance performed on the three principal components indicated that only the first component, male dominance, differed significantly among the males ( $F = 15.931$ ;  $df = 3,20$ ;  $P < 0.001$ ).

The mean and standard errors for each male for the first two principal components (PC1 and PC2) are plotted in Figure 1. The origin represents the mean values for both components across all males. Each quadrant of the plot is labeled to reflect the interpretation of PC1 and PC2. Positive values of PC1 indicated dominance, while negative values indicated submission. Positive values of PC2 indicated aggression, while negative values were considered friendliness. Mean values for the four males fell in three different quadrants. Two males were subordinate/friendly, one was subordinate/aggressive and one was dominant/aggressive. The male who had copulated with females in past encounters was subordinate/friendly. The dominant/aggressive male was the individual that was apparently incompatible with a familiar female in the estrogen study. Although the present sample size is too small to draw generalizations, it appears that persistence (as measured by male Approaches and dominance) does not necessarily correlate with reproductive success ■

### Figure Legends

**Figure 1.** Means ( $\pm$ SE) for four male kangaroo rats for the first two principal components of a principal components analysis of male behavior during dyadic interactions with anestrus females. The first principal component (PC1, explaining 42.4% of the variance) is interpreted as male dominance, while the second component (PC2, explaining 28.1% of the variance) represents aggression. The origin indicates mean values for all males.

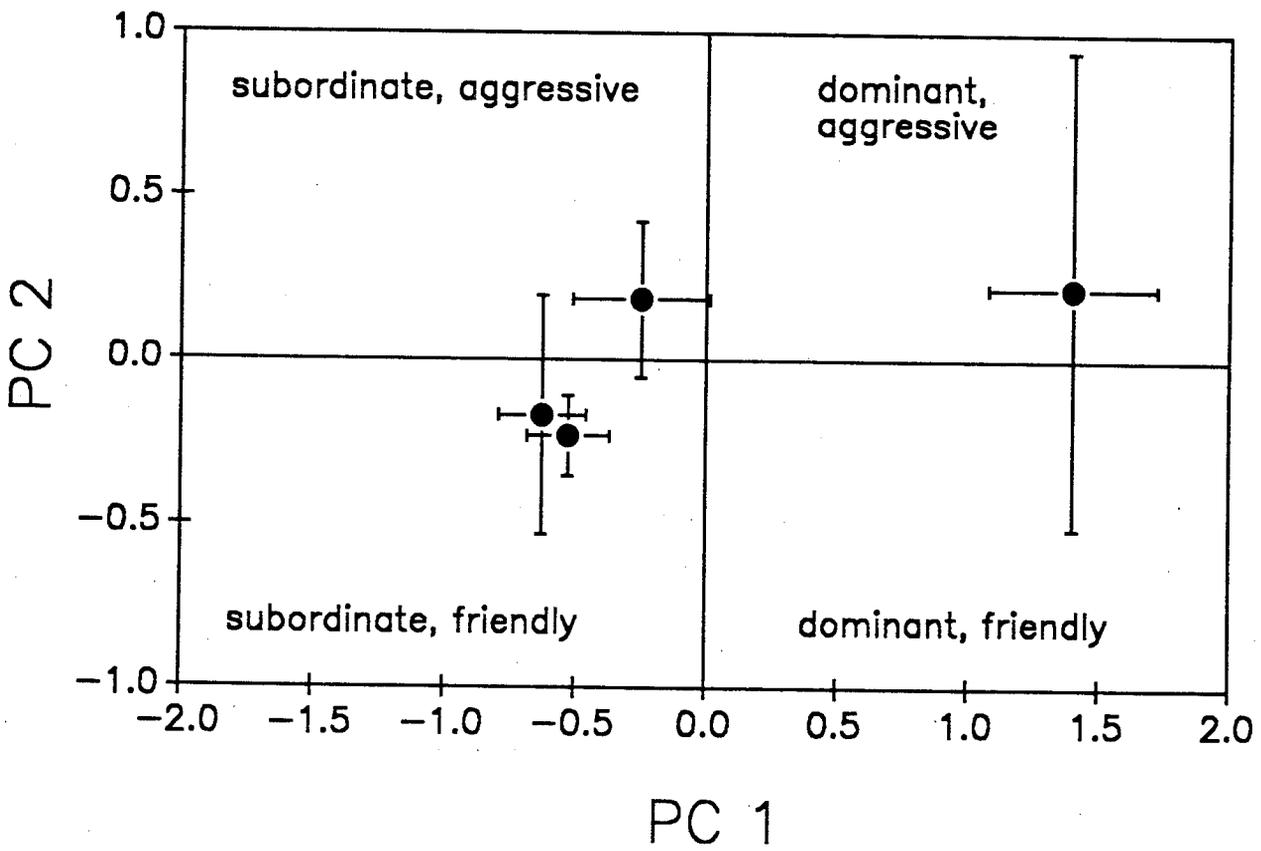
**Table 1.** Univariate analyses of variance performed on eight behavioral variables during dyadic interactions of male and female kangaroo rats.

Behavior	F	P (df = 3,20)
Male Approach	14.947	0.000
Male Depart	2.139	0.127
Female Approach	0.885	0.466
Female Depart	10.589	0.000
Attack frequency	6.091	0.004
Attack duration	3.360	0.039
Contact frequency	0.709	0.558
Contact duration	0.433	0.731

**Table 2.** Component loadings and percent of variance explained by each component for a principal components analysis performed on eight behavioral variables during dyadic encounters between male and female kangaroo rats.

Variable	Component Loading		
	PC1	PC2	PC3
Male Approach	0.933	0.077	0.163
Male Depart	-0.628	0.218	0.695
Female Approach	-0.522	0.347	0.752
Female Depart	0.900	-0.102	0.131
Attack frequency	0.688	0.640	0.213
Attack duration	0.606	0.654	0.215
Contact frequency	0.348	-0.770	0.479
Contact duration	0.288	-0.797	0.401
[% variance explained	42.4	28.1	19.7]

**Figure 1**



## Effects of Housing Temperature on Body Condition and Reproductive Potential of Dipodomys heermanni

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Previous studies of the energetics of *D. heermanni* at the National Zoological Park (Roberts and Rall, 1991) have shown that thermalneutrality lies between 28.5°C and 32°C (i.e. animals increased their metabolic rates at ambient temperatures above and below the upper and lower critical temperatures, respectively). If maintained consistently at temperatures outside thermalneutrality, animals must increase food and/or water intake to maintain constant body mass. The difference in intake levels required to maintain constant body mass between an individual within thermalneutrality and the same individual outside thermalneutrality is essentially the "cost" of thermoregulation. We have estimated that animals exposed to "standard" laboratory temperatures (20-24°C, i.e.. outside thermalneutrality) have approximately a 20% higher metabolic rate than those housed within thermalneutrality. [Roest's and Rathbun's colonies were maintained at ambient temperatures substantially below the lower critical temperature. Animals in these colonies were/are most likely under energetic stress and at a risk of losing weight and/or condition].

In the absence of some physiological or behavioral means of conserving energy (e.g. torpor, huddling or reducing activity), animals outside thermalneutrality must offset the increased costs of thermoregulation by either increasing energy intake or improving the efficiency of food conversion to usable energy. Failure to adjust accordingly results in a negative energy balance and subsequent loss of weight and condition. Kangaroo rats in general appear not to deposit body fat as a means of storing "surplus" energy but have evolved elaborate food caching behaviors as an alternative energy storage strategy. Caches may be used both to maintain constant body condition during seasonal periods of food shortage and temperature extremes and also to support the increased costs of reproduction (e.g. increased activity, gestation and lactation). Even if food caches are available, the convertibility of energy reserves into reproduction may depend on the degree of energetic stress imposed on the individual, that is, on how much energy remains (or can be converted) available for reproduction etc. after requirements for thermoregulation are accommodated. Females may have higher energetic requirements for reproduction than males, although there is some conjecture on this point.

It was previously determined that *D. heermanni* at NZP housed at 23°C and fed *ad lib*, self selected diets did not deposit significant fat reserves (Roberts and Rall, 1991) suggesting that they may have difficulty mobilizing sufficiently energy for reproduction. Size and condition-based life history theory suggests that individuals in marginal or poor body condition, having virtually no reserves to devote to reproduction, may "choose" to significantly reduce, or even forego, energetic expenditures on reproduction. At the National Zoological Park, 3 *D. h. morroensis* and *D. h. arenae* females in less than average body condition cycled significantly less frequently than animals in better body condition (Roberts and Rall, 1991). Thus, it is clearly possible that there may be a critical link between the thermal environment in which animals are maintained, their body condition and their rates of reproduction.

One of the most important objectives of endangered species captive breeding is to increase population size as rapidly as possible. Because mortality rates in captive populations of kangaroo rats have tended to be rather high, it is clearly desirable to find a means of maximizing the number of breeding opportunities for an individual over a given period of time (i.e. especially maximizing estrous cycle rates for females of uncertain life expectancy) and to increase survivorship (i.e. prolong reproductive lifespan). Thus, we felt it necessary to determine the relationship between thermal environment, body condition, estrous cycling rates, longevity and reproductive "potential".

The purpose of this experiment was to examine the relationship between food consumption rates, body condition and behavior in two groups of individuals housed under two different thermal regimes, one below the thermal-critical temperature and another within thermalneutrality. Our hypothesis was that animals housed outside of thermalneutrality would increase food consumption in order to meet the increased demands on thermoregulation and would either maintain or decline in body weight and condition. Animals housed within thermalneutrality would either maintain constant food intake and increase body weight and condition or decrease food intake and maintain body weight and condition.

## Methods

### Selection of test groups

Two test groups with similar body condition profiles were assembled. Body condition indices ( $CI = \text{body weight}/\text{head-body length}$ ) were calculated for all potential candidates (in this case they were all males as all females were reserved for breeding encounters). To qualify for a treatment group, an individual's CI had to fall between  $-1/2$  standard deviation (sd) and  $+ 1$  sd of the mean of the entire population of 23 males and females. Thus, experimental subjects were in slightly lower than to somewhat greater than mean CI. Qualifying individuals' were also required to have CI's meeting this criterion for at least six weeks prior to the onset of the experiment (i.e. their CI's had to be relatively stable). Nine qualifying males were assigned to either the high temperature (HT =  $31^{\circ}\text{C}$ ) or low temperature (LT =  $23.5^{\circ}\text{C}$ ) experimental group on the basis of randomized matched pairs so that each group had similar distribution of CIs. The HT group consisted of two *morroensis* and three *arenae* and the LT group consisted of one *morroensis* and three arena.

Animals were placed in climate control rooms in individual 10 gallon aquaria each supplied with sand substrate, nesting material and a single wooden nestbox. The climate control rooms were maintained  $1/2^{\circ}\text{C}$  of their assigned temperatures. Relative humidities ranged from approximately 28-30% in the HT regime and 38-42% in the LT regime; permanent temperature and humidity records were made for each room on a recording hygrothermograph. Nestbox temperatures were taken in each enclosure once a week. Photoperiod for both temperature regimes was 10L:14D.

Before starting the experiment, we placed one female and three male non-candidates, each with stable CI, on the experimental diet of mouse chow and lettuce for four days to determine if they would accept it satisfactorily. Mouse chow was selected because of its homogeneous composition, balanced nutritional composition, and ease of handling, recovery and weighing. Once it was determined that animals would accept the experimental diet, the experimental groups were acclimated to it in their home

cages in the main animal holding rooms for four days. They were then moved to the climate control rooms where they were allowed to acclimate again at home cage temperatures (approximately 28°C) for three days before temperatures were gradually changed to the experimental ones.

Each animal was fed 20g mouse chow (i. e. *ad lib*), 12g romaine lettuce and water *ad lib* each day at approximately 1000h. Animals were weighed daily and food intakes were determined by subtracting the weight of food remaining from food offered the previous day. Cached food was removed from nestboxes and enclosure floors daily; water intake was not recorded.

Seven additional animals whose CIs were greater than 1/2 sd below the population mean were also placed in the HT room in an attempt to increase CI. Because these animals were not strictly on the experimental regime, they continued to receive the normal colony diet of seed mix, rolled oats, mouse chow and lettuce. Their weights were taken twice a week but food intake was not measured.

The experiment was conducted in two phases: Phase 1, lasting from October 7 to November 26, 1991, included monitoring of weights, food intake and behavior. Phase 2, continued until approximately March 15 and included only monitoring of weights and food intakes.

Activity monitoring commenced on day nine of the experiment (October 16) and continued for 41 days (Until November 26). All animals typically were very active at the onset of the scotophase as they emerged from their nestboxes and began eating. Therefore, activity observations commenced at least one hour after the beginning of the scotophase when animals were less likely to be eating. Each room was observed for one 30 minute observation session four times per week during which one minute observation scans were made of each individual. Activity for each enclosure during each scan was classified as one of four activity states: 1) In nestbox, activity unknown but presumed resting; 2) Out of nestbox and moving in enclosure; 3) Out of nestbox and resting in enclosure; 4) Out of nestbox but out of sight (e.g. behind nestbox). The number of scan samples for each state was tallied at the end of the observation period.

## Results

### Phase 1:

There was no significant difference in mean daily weight change between the 31°C (HT) group (mean = +0.033g/day; sd = 1.24g; N = 210) and the 23.5°C (LT) group (mean = +0.017g/day; sd = 1.035; N = 167) ( $t = 0.134$ ;  $df = 375$ ).

The LT group consumed significantly more dry food (mouse chow) per day (mean = 4.3g dry food/day; sd = 0.8; N = 164) than the HT group (mean = 4.06g dry food/day; sd = 1.13g; N = 204) ( $t = 2.29$ ;  $df = 366$ ;  $p < 0.05$ ) and significantly less lettuce per day (mean = 10.55g lettuce/day; (sd = 1.59; N = 164) than the HT group (mean = 11.2g lettuce/day; sd = 0.67g; N = 205) ( $t = 5.29$ ;  $df = 366$ ;  $p < 0.001$ ).

The animals in the HT room were out of the nestbox and active significantly more (mean = 14.33min./day; sd = 11.34; N = 74) than those in the LT room (mean = 5.19min./day; sd = 6.39; N = 63) ( $t = 5.67$ ;  $df = 135$ ;  $p < 0.001$ ). Animals in the HT room also spent significantly less time out of sight in their nestboxes (mean = 9.98min./day; sd = 12.39; N = 74) than those in the LT room (mean = 20.42min./day; sd = 11.26; N = 63) ( $t = 5.17$ ;  $df = 135$ ;  $p < 0.001$ ).

Daily food intake was significantly correlated with daily number of minutes active for animals on the HT treatment ( $r_s = 0.64$ ;  $df = 78$ ;  $p < 0.01$ ) LT but not for those on the LT treatment.

Nestbox temperatures for the HT group were virtually identical with ambient temperatures (i.e. 31°C) at the beginning and end of the experiment. Nest temperatures for the LT group, however, ranged from 0.5°C to 1.5°C higher than ambient. Animals under the LT regime also constructed larger and more elaborate nests than did the HT group (nest structure was not quantified however).

### Phase 2:

At the completion of Phase 2, the mean total percentage weight differences was marginally significantly higher in the HT group (mean = +5.2%; sd = 6.4%; N = 5) than in the LT group (mean = -4.2%; sd = 6.5%;  $df = 4$ ) ( $t = 2.17$ ;  $df = 7$ ;  $p < 0.05$ ) (Figure 1). The HT group also had significantly higher mean daily dry food intakes (mean = 3.77 g/day; sd = 0.76; N = 133) than the LT group (mean = 3.29 g/day; sd = 0.904; N = 135) ( $t = 4.7$ ;  $df = 266$ ;  $p < 0.001$ ) (Figure 2). Mean daily lettuce consumption was not significantly different between the two groups.

Only four of the six additional animals placed in the HT room survived to the end of Phase 2. At the end of Phase 2, the mean body weights of the surviving animals had increased by approximately 4.9% (from mean = 59.8g; sd = 2.61; N = 6 to mean = 62.8g; sd = 3.33; N = 4). This change was not statistically significant ( $t = 1.48$ ;  $df = 8$ ).

## Discussion

Although the LT group consumed significantly more dry food (i.e. concentrate) than the HT group during Phase 1, there was no significant difference in mean weights changes in the two groups. The increased energetic demand of the lower temperature was apparently compensated by increased intake. The LT group also responded to the lower temperature regime by becoming less active and spending a higher percentage of time inside nestboxes that had more complex nests and were marginally warmer, relative to ambient temperatures, than those in the HT group. Animals in the HT group frequently rested outside their nestboxes, often stretching out on their abdomens as if attempting to "dump" heat. The HT group's significantly greater lettuce consumption suggested that they may have been compensating for increased respiratory water loss at the higher temperature.

Over the longer term, i.e. by the end of Phase 2, the HT group was significantly heavier than the LT group. This was in part due to weight gain by the HT group but was also due to a significant weight decline in the LT group. Mean daily food consumption declined somewhat in both groups over the course of the experiment, but by the end of Phase 2 food consumption was significantly greater in the HT group than the LT

group. This suggested that the HT group acclimated successfully to the higher temperature regime and was able to increase body mass even while reducing food intake and displaying relatively high levels of activity. Conversely, the LT group did not acclimate sufficiently to maintain starting weights (although weights at the end of Phase 2 were increasing in this group).

Animals in the LT group also adopted a very different behavioral strategy by reducing total activity and increasing thermal buffering as much as possible, apparently to reduce the negative impact of increased conductance. The decline in this group's food intake is somewhat puzzling. It may have been a temporary phenomenon, as intakes and weights were increased in the last 20 days of the experiment. We conjecture that if the LT group had access to food caches it may have increased intakes and possibly maintained higher weights although it seems unlikely that their performance would have equaled or exceeded the HT group if it too was permitted access to caches.

The management recommendations emerging from these findings are as follows:

1. To maintain adequate body condition, and hence maximize reproductive potential, *D. heermanni* should be housed at temperatures at or near thermalneutrality (28°C-32°C).
2. Animals maintained at any temperatures on a dry food (i.e. concentrate) diet should have access to free water (i.e. either in bowls or in lettuce or other vegetation). This appears to be a necessary adjunct to enhanced intake.
3. Animals permitted access to food caches may maintain a higher plane of condition for longer than animals without cached reserves.
4. Because animals maintained within thermalneutrality are more active and display distinctly different behaviors and patterns of behavior than those at lower temperatures, the thermal environment may influence the location, rate and nature of social interactions.
5. If animals are exposed to temperatures below the lower critical temperature, they should be provided with a sufficient quantity and quality of nest material to be able to construct nests that will reduce conductance and enhance energy conservation (i.e. to buffer against low temperatures).
6. Thermal "therapy", coupled with a high plane of nutrition, may be a useful tool for improving body condition in some animals in poor or marginal condition ■

## Figure Legends

**Figure 1.** Mean standardized weight changes in the two temperature treatment groups (HT: 31 C and LT: 23.5 C). Standardized weights for each animal were calculated by dividing its current weight by its weight at the beginning of the experiment. Thus each day's standardized weight change is the difference between the day's weight and the kangaroo rat's beginning weight. Means for each group were calculated by averaging the standardized weights for all animals in each group.

**Figure 2.** Percent daily differences in intake between the HT and LT groups. Each bar represents the difference between the means of individual daily intakes for each group. Hence, bars projecting above the zero baseline indicate that the mean daily intake for the HT group was greater than the mean daily intake for the LT group. The magnitude of the difference is expressed as a percentage of mean daily intake for both groups.

**Figure 3.** Weight changes for the non-experimental animals placed in the HT regime for "therapeutic" purposes. The abscissa indicates the number of days from the onset of the HT regime.

Figure 1

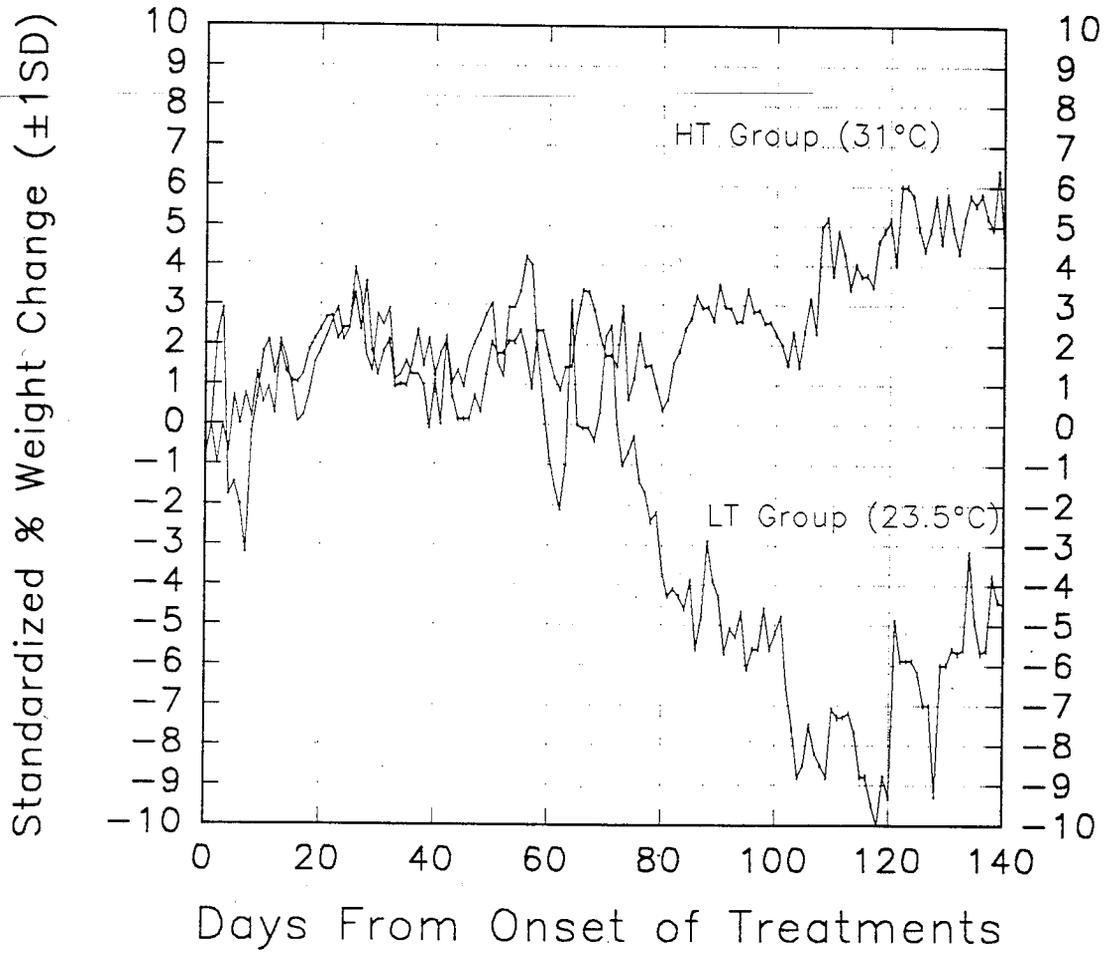


Figure 2

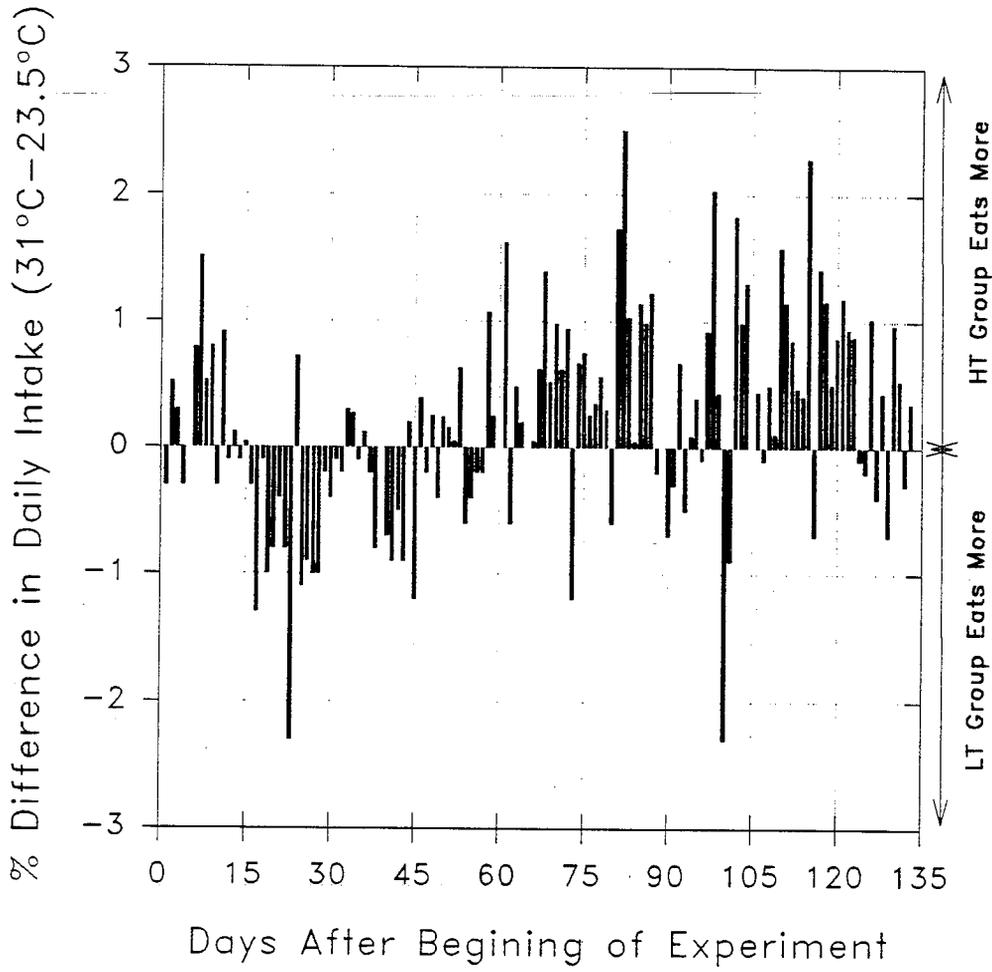
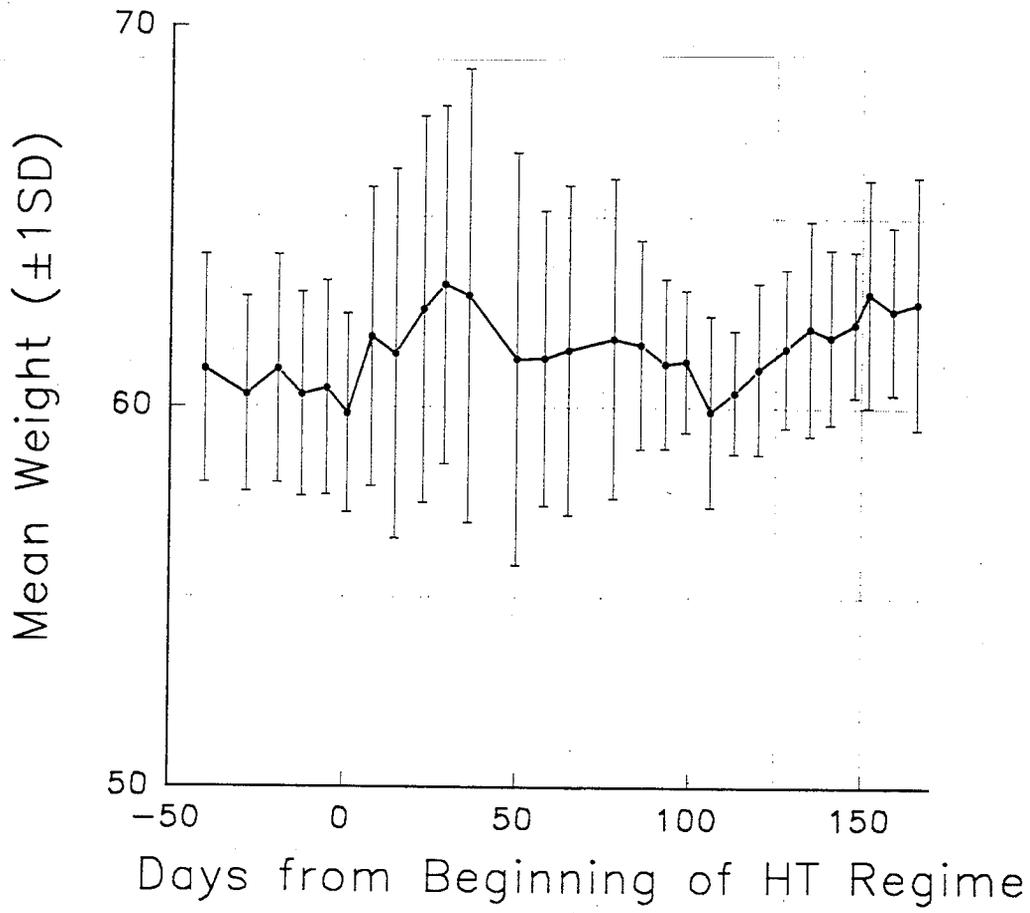


Figure 3



## Prospects for Applying Reproductive Biotechnology to the Conservation of the Morro Bay Kangaroo Rat (*Dipodomys heermanni morroensis*)

William F. Rall,  
Department of Animal Health

During the past four decades, a number of reproductive biotechniques have been developed using laboratory and domestic livestock that have great promise in efforts to conserve threatened populations of animals. The most promising reproductive biotechniques are the collection and cryopreservation of animal germ plasm (spermatozoa, embryos and oocytes) and the associated biotechniques, artificial insemination and embryo transfer. Although these procedures are commonly and routinely applied to the breeding of domesticated animals, there are few examples of the use of these procedures for strictly conservation purposes. In the case of semen cryopreservation, normal offspring have been reported following artificial insemination with frozen-thawed sperm in a total of 31 mammalian species. But even though approximately half of these species represent "non-domesticated" species, the total number of offspring produced has been modest (in many cases only one and none more than 15).

The reasons for the lack of widespread application of reproductive biotechniques for conservation purposes are manifold. Several prerequisites to the successful application of these procedures can be identified. First and foremost is an organizational infrastructure, on a national or international level, for developing and overseeing the development of animal germ plasm banking programs. Recent efforts by the American Association of Zoological Parks and Aquariums (AAZPA) and the Captive Breeding Specialists Group (CBSG) of the International Union for the Conservation of Nature are developing structures for such programs.

The second requirement is need for basic information concerning the reproductive physiology and behavior of the target species. For example, the use of cryopreserved spermatozoa requires, at minimum, a knowledge of the length of the estrous cycle and accurate methods for identifying the appropriate time for artificial insemination. Usually the best results are obtained when basic and applied research has established the length and variability of estrous cycle, determined the impact of seasonality on reproductive success, and identified optimal methods for synchronizing estrus, predicting ovulation, diagnosing pregnancy and impending parturition, and collecting, cryopreserving and inseminating spermatozoa.

A third requirement is the ability to breed and manage the target species in captivity. The inability to produce viable offspring is diagnostic of a lack of sufficient background information concerning the target species. Unfortunately, this remains a important barrier to the application of reproductive biotechniques to the Morro Bay kangaroo rat (and other kangaroo rats). Even in those *Dipodomys* species where successful captive breeding has been reported, the number of animals that actually produced litters was a small portion of the total number paired.

In conclusion, further progress on the captive breeding of *Dipodomys* species must be made before reproductive biotechniques could play any important role in conservation efforts for the Morro Bay kangaroo rat.

**Recovery Of Spermatozoa From Elderly Lompoc and Merro Bay Kangaroo Rats During Post-Mortem Examination**

During the past two years, the epididymis and vas of a total of four elderly male kangaroo rats have been examined for spermatozoa shortly after natural death. In each case morphologically spermatozoa were recovered and the concentration of sperm isolated from both regions was similar to that observed in fertile laboratory mice and rats. In one case, a small proportion of the spermatozoa exhibited normal motility.

These observations indicate that *Dipodomys heermanni* continue to produce spermatozoa until at least 4.2 years of age. This suggests that male infertility is not a cause of captive breeding failure ■

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## Appendices

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Report Start Date:  
initiation

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: **DIPODOMYS HEERMANNI MORROENSIS**  
Common Name: **MORRO BAY KANGAROO RAT**

ID's: Spec.Id	House/Tag/Tattoo/ Studbook/Cage	Sex/Age	Dates: Birth/In/Out	Terms:	Origin/ Party:	Dam-Sire Their Id
109820	322/ Removed RED TAG (LEFT EA /// ///	Male 6Y,2M,10D	21 Jun 1986 19 Nov 1990 29 Aug 1992	Captive born Loan from Death	SAN SIMEON USDI LAW	 322
109821	325/ Removed BLUE (RIGHT EAR) /// ///	Male 5Y,6M,6D	21 Jun 1986 19 Nov 1990 25 Dec 1991	Captive born Loan from Death	SAN SIMEON USDI LAW	 325
109822	330/ Removed RED (RIGHT EAR)/ /// ///	Male 4Y,11M,13D	6 Oct 1986 19 Nov 1990 18 Sep 1991	Captive born Loan from Death	SAN SIMEON USDI LAW	 330
109823	349/ 349 (RIGHT EAR)/ /// ///	Male 5Y,4M,26D	21 Jul 1987 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	 349
109824	326/ Removed 326 (LEFT EAR)// // ///	Female 5Y,11M,2D	13 Jun 1986 19 Nov 1990 14 May 1992	Captive born Loan from Death	SAN SIMEON USDI LAW	 326
109825	327/ 327 (LEFT EAR)// // ///	Female 6Y,6M,4D	13 Jun 1986 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	 327
109826	348/ 34_ (RIGHT EAR)/ /// ///	Female 5Y,4M,26D	21 Jul 1987 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	 348

Report Start Date:  
initiation

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: **DIPODOMYS HEERMANNI MORROENSIS**  
Common Name: **MORRO BAY KANGAROO RAT**

Page 2

**Current Inventory Summary as of Report End Date: 14 Dec 1992**

Totals: 1.2.0 Animals (3)	3 Captive Born
3 In on Loan	0 Wild Born
0 Out on Loan	0 Birth Type Unknown

**Historic Inventory Summary as of Report End Date: 14 Dec 1992**

7 Captive Born
0 Wild Born
0 Birth Type Unknown

**Acquisition Summary:**

0.0.0 by birth (0)
4.3.0 from elsewhere (7)

**Disposition Summary:**

3.1.0 by death (4)
0.0.0 by sale, trade, donation (0)
0.0.0 by loans (0)
0.0.0 by escape, release, theft (0)

ISIS/ARKS  
14 Dec 1992

Report Start Date:  
1 Oct 1991

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: **DIPODOMYS HEERMANNI MORROENSIS**  
Common Name: **MORRO BAY KANGAROO RAT**

ID's: Spec.Id	House/Tag/Tattoo/ Studbook/Cage	Sex/Age	Dates: Birth/In/Out	Terms:	Origin/ Party:	Dam-Sire Their Id
109820	322/ Removed RED TAG (LEFT EA /// ///	Male 6Y,2M,10D	21 Jun 1986 19 Nov 1990 29 Aug 1992	Captive born Loan from Death	SAN SIMEON USDI LAW	322
109821	325/ Removed BLUE (RIGHT EAR) /// ///	Male 5Y,6M,6D	21 Jun 1986 19 Nov 1990 25 Dec 1991	Captive born Loan from Death	SAN SIMEON USDI LAW	325
109823	349/ 349 (RIGHT EAR)/ /// ///	Male 5Y,4M,26D	21 Jul 1987 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	349
109824	326/ Removed 326 (LEFT EAR)// // //	Female 5Y,11M,2D	13 Jun 1986 19 Nov 1990 14 May 1992	Captive born Loan from Death	SAN SIMEON USDI LAW	326
109825	327/ 327 (LEFT EAR)// // //	Female 6Y,6M,4D	13 Jun 1986 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	327
109826	348/ 34_ (RIGHT EAR)/ /// ///	Female 5Y,4M,26D	21 Jul 1987 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	348

Current Inventory Summary as of Report End Date: 14 Dec 1992

Totals: 1.2.0 Animals (3)	3 Captive Born
3 In on Loan	0 Wild Born
0 Out on Loan	0 Birth Type Unknown

Historic Inventory Summary as of Report End Date: 14 Dec 1992

6 Captive Born
0 Wild Born
0 Birth Type Unknown

Acquisition Summary:

0.0.0 by birth (0)
3.3.0 from elsewhere (6)

Disposition Summary:

2.1.0 by death (3)
0.0.0 by sale, trade, donation (0)
0.0.0 by loans (0)
0.0.0 by escape, release, theft (0)

Report Start Date:

Transaction Report

Report End Date:

1 Oct 1991

NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

14 Dec 1992

Transaction Description: Death

for DIPODOMYS HEERMANNI MORROENSIS

Spec.Id	Taxon Name/Common Name	Sex/Age	Tran_Date	Party/Id
109820	DIPODOMYS HEERMANNI MORROENSIS morro bay kangaroo rat 322/RED TAG (LEFT EAR)//	Male 6Y,2M,10D Death	29 Aug 1992 29 Aug 1992	DZRFREEZR
			by Other/Unknown	
109821	DIPODOMYS HEERMANNI MORROENSIS morro bay kangaroo rat 325/BLUE (RIGHT EAR)//	Male 5Y,6M,6D Death	25 Dec 1991 25 Dec 1991	DZRFREEZR
			by Other/Unknown	
109824	DIPODOMYS HEERMANNI MORROENSIS morro bay kangaroo rat 326/326 (LEFT EAR)//	Female 5Y,11M,2D Death	14 May 1992 14 May 1992	DZRFREEZR
			by Other/Unknown	

Note: Age is calculated as of the Removal Date...

Report Start Date:  
initiation

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: DIPODOMYS HEERMANNI ARENAE

Common Name: LOMPOC KANGAROO RAT

ID's: Spec.Id	House/Tag/Tattoo/ Studbook/Cage	Sex/Age	Dates: Birth/In/Out	Terms:	Origin/ Party:	Dam-Sire Their Id
109827 Removed	335/ BLACK (RIGHT EAR /// ///	Male 3Y,10M,1D	11 Feb 1987 19 Nov 1990 12 Dec 1990	Captive born Loan from Death	SAN SIMEON USDI LAW	335
109828 Removed	336/METAL 33_K// //	Male 4Y,2M,5D	11 Feb 1987 19 Nov 1990 17 Apr 1991	Captive born Loan from Death	SAN SIMEON USDI LAW	336
109829 Removed	344/ 84 (LEFT EAR)/// /	Male 5Y,2M,6D	17 Apr 1987 19 Nov 1990 21 Jun 1992	Captive born Loan from Death	SAN SIMEON USDI LAW	344
109830	382/////	Male 6Y,9M,13D	4 Mar 1986 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	382
109831 Removed	334/ 484 (LEFT EAR)// //	Female 4Y,7M,6D	11 Feb 1987 19 Nov 1990 17 Sep 1991	Captive born Loan from Death	SAN SIMEON USDI LAW	334
109832	343/////	Female 5Y,7M,30D	17 Apr 1987 19 Nov 1990	Captive born Loan from	SAN SIMEON USDI LAW	343
110026	1////TB1RAQ/	Male ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER,CA	
110027	2////TB1RAQ/	Male ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER,CA	
110028	3////TB1RAQ/	Male ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER,CA	
110029	4////TB1FWD28/	Male ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER,CA	
110030 Removed	5/////	Male ~1Y	~10 Apr 1990 10 Apr 1991 29 Nov 1991	Wild born Acq from Wild Death	CALENDER,CA	
110031 Removed	6/////	Male ~2Y	~10 Apr 1990 10 Apr 1991 27 Jun 1992	Wild born Acq from Wild Death	CALENDER,CA	
110032	7////TB1FWD26/	Male ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER,CA	
110033 Removed	8/////	Female ~2Y	~10 Apr 1990 10 Apr 1991 11 Jul 1992	Wild born Acq from Wild Death	CALENDER,CA	

Report Start Date:  
initiation

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: **DIPODOMYS HEERMANNI ARENAE**  
Common Name: **LOMPOC KANGAROO RAT**

Page 2

Identification:		Dates:	Terms:	Origin/ Dam-Sire
Spec.Id	House/Tag/Tattoo Sex/Age	Birth/In/Out		Party: Their Id
110034	9///// Female ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER, CA
110035	10//////TB1RAQ/ Female ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER, CA
110036	11//////TB1RAQ/ Female ~2Y	~10 Apr 1990 10 Apr 1991	Wild born Acq from Wild	CALENDER, CA
110039	12//////TB1RAQ/ Male 1Y,8M,1D	15 Apr 1991 15 Apr 1991	Captive born Birth	110035 UNK
110040	13//////TB1RAQ/ Male 1Y,8M,1D	15 Apr 1991 15 Apr 1991	Captive born Birth	110035 UNK
110041	14//////TB1F25WD/ Female 1Y,8M,1D	15 Apr 1991 15 Apr 1991	Captive born Birth	110035 UNK
110283	15///// Male ~2Y	~ 1 Oct 1990 1 Oct 1991	Wild born Acq from Wild	CALENDER
110284 Removed	16///// Male ~2Y	~ 1 Oct 1990 1 Oct 1991 25 Nov 1992	Wild born Acq from Wild Death	CALENDER
110285	17//////TB1RAQ/ Male ~2Y	~ 1 Oct 1990 1 Oct 1991	Wild born Acq from Wild	CALENDER
110286	18//////TB1F28WD/ Female ~2Y	~ 1 Oct 1990 1 Oct 1991	Wild born Acq from Wild	CALENDER
110287	19//////TB1FWD29/ Female 1Y,7M,2D	14 May 1991 1 Oct 1991	Captive born Acq from Wild	CALENDER
110288	20//////TB1FWD27/ Female 1Y,7M,2D	14 May 1991 1 Oct 1991	Wild born Acq from Wild	CALENDER
110289	21//////TB5R/ Female 1Y,7M,2D	14 May 1991 1 Oct 1991	Wild born Acq from Wild	CALENDER
110290	22//////TB1FWD27/ Female 1Y,2M,14D	1 Oct 1991 1 Oct 1991	Wild born Acq from Wild	CALENDER

Report Start Date:  
initiation

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: DIPODOMYS HEERMANNI ARENAE  
Common Name: LOMPOC KANGAROO RAT

Page 3

Current Inventory Summary as of Report End Date: 14 Dec 1992

Totals: 10.10.0 Animals (20)	6 Captive Born
2 In on Loan	14 Wild Born
0 Out on Loan	0 Birth Type Unknown

Historic Inventory Summary as of Report End Date: 14 Dec 1992

10 Captive Born
18 Wild Born
0 Birth Type Unknown

Acquisition Summary:

2.1.0 by birth (3)
14.11.0 from elsewhere (25)

Disposition Summary:

6.2.0 by death (8)
0.0.0 by sale, trade, donation (0)
0.0.0 by loans (0)
0.0.0 by escape, release, theft (0)

ISIS/ARKS  
14 Dec 1992

Report Start Date:  
1 Oct 1991

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: **DIPODOMYS HEERMANNI ARENAE**  
Common Name: **LOMPOC KANGAROO RAT**

ID's: Spec.Id	House/Tag/Tattoo/ Studbook/Cage	Sex/Age	Dates: Birth/In/Out	Terms:	Origin/ Party:	Dam-Sire Their Id
109829	344/	Male	17 Apr 1987	Captive born	SAN SIMEON	
Removed	84 (LEFT EAR)///	5Y,2M,6D	19 Nov 1990	Loan from	USDI LAW	344
	/		21 Jun 1992	Death		
109830	382/////	Male	4 Mar 1986	Captive born	SAN SIMEON	
		6Y,9M,13D	19 Nov 1990	Loan from	USDI LAW	382
109832	343/////	Female	17 Apr 1987	Captive born	SAN SIMEON	
		5Y,7M,30D	19 Nov 1990	Loan from	USDI LAW	343
110026	1////TB1RAQ/	Male	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110027	2////TB1RAQ/	Male	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110028	3////TB1RAQ/	Male	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110029	4////TB1FWD28/	Male	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110030	5/////	Male	~10 Apr 1990	Wild born	CALENDER,CA	
Removed		~1Y	10 Apr 1991	Acq from Wild		
			29 Nov 1991	Death		
110031	6/////	Male	~10 Apr 1990	Wild born	CALENDER,CA	
Removed		~2Y	10 Apr 1991	Acq from Wild		
			27 Jun 1992	Death		
110032	7////TB1FWD26/	Male	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110033	8/////	Female	~10 Apr 1990	Wild born	CALENDER,CA	
Removed		~2Y	10 Apr 1991	Acq from Wild		
			11 Jul 1992	Death		
110034	9/////	Female	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110035	10////TB1RAQ/	Female	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110036	11////TB1RAQ/	Female	~10 Apr 1990	Wild born	CALENDER,CA	
		~2Y	10 Apr 1991	Acq from Wild		
110039	12////TB1RAQ/	Male	15 Apr 1991	Captive born	110035	UNK
		1Y,8M,1D	15 Apr 1991	Birth		

Report Start Date:  
1 Oct 1991

Taxon Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Taxon Name: DIPODOMYS HEERMANNI ARENAE  
Common Name: LOMPOC KANGAROO RAT

Page 2

Identification:		Dates:	Terms:	Origin/ Dam-Sire
Spec.Id	House/Tag/Tattoo Sex/Age	Birth/In/Out		Party: Their Id
110040	13////TB1RAQ/ Male 1Y,8M,1D	15 Apr 1991 15 Apr 1991	Captive born Birth	110035 UNK
110041	14////TB1F25WD/ Female 1Y,8M,1D	15 Apr 1991 15 Apr 1991	Captive born Birth	110035 UNK
110283	15/////	~ 1 Oct 1990 1 Oct 1991	Wild born Acq from Wild	CALENDER
110284 Removed	16/////	~ 1 Oct 1990 1 Oct 1991 25 Nov 1992	Wild born Acq from Wild Death	CALENDER
110285	17////TB1RAQ/ Male ~2Y	~ 1 Oct 1990 1 Oct 1991	Wild born Acq from Wild	CALENDER
110286	18////TB1F28WD/ Female ~2Y	~ 1 Oct 1990 1 Oct 1991	Wild born Acq from Wild	CALENDER
110287	19////TB1FWD29/ Female 1Y,7M,2D	14 May 1991 1 Oct 1991	Captive born Acq from Wild	CALENDER
110288	20////TB1FWD27/ Female 1Y,7M,2D	14 May 1991 1 Oct 1991	Wild born Acq from Wild	CALENDER
110289	21////TB5R/ Female 1Y,7M,2D	14 May 1991 1 Oct 1991	Wild born Acq from Wild	CALENDER
110290	22////TB1FWD27/ Female 1Y,2M,14D	1 Oct 1991 1 Oct 1991	Wild born Acq from Wild	CALENDER

Report Start Date:

Taxon Report

Report End Date:

1 Oct 1991

NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

14 Dec 1992

Taxon Name: DIPODOMYS HEERMANNI ARENAE

Page 3

Common Name: LOMPOC KANGAROO RAT

Current Inventory Summary as of Report End Date: 14 Dec 1992

Totals: 10.10.0 Animals (20)

6 Captive Born

2 In on Loan

14 Wild Born

0 Out on Loan

0 Birth Type Unknown

Historic Inventory Summary as of Report End Date: 14 Dec 1992

7 Captive Born

18 Wild Born

0 Birth Type Unknown

Acquisition Summary:

2.1.0 by birth (3)

12.10.0 from elsewhere (22)

Disposition Summary:

4.1.0 by death (5)

0.0.0 by sale, trade, donation (0)

0.0.0 by loans (0)

0.0.0 by escape, release, theft (0)

ISIS/ARKS  
14 Dec 1992

Report Start Date:  
1 Oct 1991

Transaction Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Transaction Description: **Direct from Wild**  
for **DIPODOMYS HEERMANNI ARENAE**

Spec.Id	Taxon Name/Common Name	Sex/Age	Tran_Date	Party/Id
110283	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat	Male ~2Y	1 Oct 1991	
110284	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat 16///	Male ~2Y Death	1 Oct 1991 25 Nov 1992	by Other/Unknown
110285	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat	Male ~2Y	1 Oct 1991	
110286	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat	Female ~2Y	1 Oct 1991	
110287	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat	Female 1Y,7M,2D	1 Oct 1991	
110288	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat	Female 1Y,7M,2D	1 Oct 1991	
110289	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat	Female 1Y,7M,2D	1 Oct 1991	
110290	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat	Female 1Y,2M,14D	1 Oct 1991	110286 WILD

Note: Age is calculated as of the Report End Date...

Report Start Date:  
1 Oct 1991

Transaction Report  
NAT'L ZOOLOGICAL PARK-ZOOL. RESEARCH

Report End Date:  
14 Dec 1992

Transaction Description: **Death**  
for DIPODOMYS HEERMANNI ARENAE

Spec.Id	Taxon Name/Common Name	Sex/Age	Tran_Date	Party/Id
109829	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat 344/84 (LEFT EAR)//	Male 5Y,2M,6D Death	21 Jun 1992 21 Jun 1992	DZRFREEZR
				by Other/Unknown
110030	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat 5///	Male ~1Y Death	29 Nov 1991 29 Nov 1991	DZRFREEZR
				by Other/Unknown
110031	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat 6///	Male ~2Y Death	27 Jun 1992 27 Jun 1992	DZRFREEZR
				by Other/Unknown
110033	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat 8///	Female ~2Y Death	11 Jul 1992 11 Jul 1992	DZRFREEZR
				by Other/Unknown
110284	DIPODOMYS HEERMANNI ARENAE lom poc kangaroo rat 16///	Male ~2Y Death	25 Nov 1992 25 Nov 1992	
				by Other/Unknown

Note: Age is calculated as of the Removal Date...

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Path #: 92-337

RAT, LOMPOC KANGAROO, DIPODOMYS HEERMANNI ARENAE

M-RODENTIA, HETEROMYIDAE

Path #: 92-337

Acc #: 110033  
Acc Date: 04/10/91

Death #: 41845  
Death Date: 07/11/92  
Necropsy Date: 07/11/92

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Sex: F	Age: 2Y +	Wt.: 50.200GM	Stay: > 30 Days
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Manner of Death: Died	Interval: < 1 HR.
Tag/Band/Tattoo: 8/	X-rayed: YES
Location at Death: ANIMAL CLINIC, DAH	Disposition: RETURN TO DZR
Submittor: FRANK KOHN, DZR	Prosector: NICHOLS
Owner/Animal Dept: DZR	

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HISTORY AND CLINICAL OBSERVATIONS:

4-10-90 Estimated (to year) date of birth; wild born in Calender, CA.  
4-10-91 Obtained from the wild.  
6-29-92 Weight - 60.7 gm.  
7-1-92 Weight - 60.4 gm.  
7-6-92 Weight - 59.4 gm.  
7-9-92 Weight - 56.3 gm.  
7-10-92 Weight - 52.5 gm; to DAH for a workup.  
7-11-92 Weight - 50.0 gm; ate no lettuce; unsteady in hindquarters. To DAH, where it died.

Measurements:

H - R = 113 mm  
Tail = 163 mm  
Girth = 66 mm  
Rt. ft. = 44 mm

7-10-92 Animal presented to DAH for weight loss. Blood work unremarkable. Physical exam unremarkable except for poor body condition. No significant findings on radiographs, Mucus plug present in vulva - many neutrophils without bacteria observed. Started antibiotics and appetite stimulators.  
7-11-92 Animal ataxic; died in afternoon.

GROSS DESCRIPTION:

The body of this adult, female Kangaroo Rat is in fair to poor nutritional condition. Subcutaneous and cavitary fat stores are scant. There is mild atrophy of the musculature. The pelage over the right inguinal area has been shaved. The hair over the perineum is matted. The skin, body orifices and skeletal system are unremarkable. The tongue, pharynx and esophagus are

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Path #: 92-337

within normal limits. Multiple coalescing ulcers measuring up to 5 mm in diameter are located in the gastric mucosa. Stomach contents are stained with partially digested blood. The intestinal tract contains a moderate amount of digesta. The liver, spleen, pancreas, kidneys, ureters, urinary bladder, uterus, lungs, trachea, heart, brain and eyes are unremarkable. The ovaries measure approximately 2 mm in diameter and contain no visible follicles.

PRELIMINARY DIAGNOSES:

Inanition

Hemorrhagic gastric ulcers

LABORATORY STUDIES:

Culture: heart blood

Photographs taken: stomach

TISSUE STATUS:

Tissue Taken for Trimming

SPECIAL REQUESTS:

Save carcass for DZR, contact Frank Kohn, 673-4753. Contact Bill Rall and pathologist for immediate post mortem.

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Path #: 92-306

RAT, LOMPOC KANGAROO, DIPDOMYS HEERMANNI ARENAE

M-RODENTIA, HETEROMYIDAE

Path #: 92-306

Acc #: 110031  
Acc Date: 04/10/91

Death #: 41814  
Death Date: 06/27/92  
Necropsy Date: 06/27/92

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Sex: M	Age: 2Y +	Wt.: 69.700GM	Stay: > 30 Days
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Manner of Death: Found Dead	Interval: < 12 HRS
Tag/Band/Tattoo: HOUSE NAME: 6	X-rayed: NO
Location at Death: CCR 1 #17	Disposition: SAVE FOR DZR
Submittor: CATHY MATHIAS, DZR	Prosector: SCHULMAN
Owner/Animal Dept: DZR	

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HISTORY AND CLINICAL OBSERVATIONS:

4-10-91 Obtained from the wild; arrived at DZR; on study (food trials/temp).  
6-25-91 Treated for coccidia.  
6-30-91 Paired with a female (no mating).  
6-24-92 Weight loss ~5 gm.  
6-25-92 Weight loss ~4 gm; to DAH for AB shots, oral AB.  
6-26-92 Seems weak, treated by DAH (shots 2x).  
6-27-92 Found dead; weight at death=70 gms.

Measurements:

Body - 143 mm  
Tail - 185 mm  
Foot - 41 mm  
Ear - 17.5 mm  
Girth - 100 mm

GROSS DESCRIPTION:

This adult, male Lompo Kangaroo Rat is in good nutritional condition based on a moderate amount of subcutaneous and body cavity fat. All body orifices are patent. The scrotum is mildly hyperemic and has a moderate amount of sand adherent to the ventral surface. All internal viscera are moderately autolyzed, otherwise there are no gross lesions of the musculoskeletal, cardiovascular or respiratory systems. The esophagus is empty. The stomach and intestines contain a moderate amount of green, creamy ingesta. The cecum is mildly distended with similar materials. The colon contains a few green, malleable fecal balls. The liver is tan-brown and extremely friable but of normal size and shape. There are no gross lesions of the thyroid, adrenal glands, pancreas, spleen, accessory sex glands or empty urinary bladder. The kidneys, testicles, and eyes are similarly unremarkable. The brain is excessively soft (marked autolysis) but otherwise unremarkable.

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Path #: 92-306

PRELIMINARY DIAGNOSES:

Moderate to marked autolysis  
Mild scrotal hyperemia with adherent sand

LABORATORY STUDIES:

Bacteriology: heart blood, colon

TISSUE STATUS:

Tissue Taken for Trimming  
Tissue Samples Ultrafrozen  
Tissues ultrafrozen: left kidney, carcass.

SPECIAL REQUESTS:

Save carcass for DZR, contact Frank Kohn, 673-4753.  
Special kangaroo rat autopsy and freezing.

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Path #: 92-298

RAT, LOMPOC KANGAROO, DIPODOMYS HEERMANNI ARENAE

M-RODENTIA, HETEROMYIDAE

Path #: 92-298

Acc #: 109829  
Acc Date: 11/19/90

Death #: 41801  
Death Date: 06/20/92  
Necropsy Date: 06/22/92

Sex: M                      Age: 5Y 2M 3D A                      Wt.: 57.600GM                      Stay: > 30 Days

Manner of Death: Found Dead                      Interval: <48 HRS  
Tag/Band/Tattoo: 344/84 (LEFT EAR)/                      X-rayed: YES  
Location at Death: ANIMAL CLINIC, DAH                      Disposition: SAVE FOR DZR  
Submittor: LISA TELL, DAH                      Prosector: BAUMGARTNER  
Owner/Animal Dept: DZR

HISTORY AND CLINICAL OBSERVATIONS:

6-20-92 Presented to DAH depressed, lethargic, hypothermic. Placed in incubator. Rx: 5% Dextrose and NaCl 1.0 ml S.Q. Enrofloxacin 6 mg S.Q. Found dead @ 4:00.

GROSS DESCRIPTION:

The body of this adult, male Lompoc Kangaroo Rat is in poor nutritional status based on absence of subcutaneous and body fat stores. The nose is dry and crusty. Abdominal skin is alopeciac and crusty. Musculoskeletal, cardiovascular and digestive systems are unremarkable. There is a 1.5 x 1.0 cm white, fluctuant mass in the left retroperitoneal space which encompasses the cranial pole of the left kidney, is attached to the left adrenal gland, and infiltrates into the sublumbar musculature. The reproductive and nervous systems are unremarkable.

PRELIMINARY DIAGNOSES:

Retroperitoneal mass R/O lymphoma, lipoma

LABORATORY STUDIES:

Culture: heart blood  
Cytology: retroperitoneal mass impressions

TISSUE STATUS:

Tissue Taken for Trimming  
Tissue Samples Ultrafrozen  
Tissues ultrafrozen: right kidney and one testis taken for kangaroo rat study.

SPECIAL REQUESTS:

Save carcass for DZR.

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Path #: 92-461

RAT, MORRO BAY KANGAROO, DIPODOMYS HEERMANNI MORROENSIS

M-RODENTIA,

Path #: 92-461

Acc #: 109820  
Acc Date: 11/19/90

Death #: 41968  
Death Date: 08/29/92  
Necropsy Date: 08/29/92

Sex: M                      Age: 6Y 2M 8D                      Wt.: 66.200GM                      Stay: > 30 Days

Manner of Death: Found Dead                      Interval: > 5 HRS.  
Tag/Band/Tattoo: 322/RED TAG (LEFT EA                      X-rayed: YES  
Location at Death: CLIM. CNTRL. ROOM #3                      Disposition: RETURN TO DZR  
Submittor: FRANK KOHN, DZR                      Prosector: DUNCAN  
Owner/Animal Dept: DZR

HISTORY AND CLINICAL OBSERVATIONS:

6-21-86    Captive born in San Simeon.    House name: 322.  
11-19-90    Loaned from USDI Fish and Wildlife Service.  
8-29-92    Found dead in nest box in the morning; no previous medical problems.

Measurements:    H - R = 130 mm  
   Tail = 151 mm  
   Rt. rear ft. = 41 mm  
   Girth = 101 mm

GROSS DESCRIPTION:

The adult, male Morro Bay Kangaroo Rat has a crown-rump length of 7.5 cm and the pelage is in good condition. There are minimal fat deposits, hydration is moderate and muscle mass is normal. The oral and anal orifices are patent, while the penis has a mucus plug. The lungs are congested and dark with regularly arranged longitudinal pale foci at the surface. The gastrointestinal tract contains food in varying stages of digestion - green fibrous material in stomach, blood-tinged mucoid material in small intestine and formed feces in colon. The liver (5.6 gm) is enlarged with a rounded border and an irregular surface with round, raised plaques of paler yellow tissue which penetrated the tissue deeply, other portions are focally much enlarged, firm and white. The accessory reproductive tract contains gelatinous grey matter and the bladder has grey-white content. No lesions seen in the salivary glands, lymph nodes, thyroids, heart, kidney, adrenal, spleen, skeletal muscle, eye, brain, sciatic nerve, testicle or epididymis.

PRELIMINARY DIAGNOSES:

Liver, adenocarcinoma  
Lung, probable multifocal emphysema

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Path #: 92-461

LABORATORY STUDIES:

Bacteriology: heart blood

Cytology: liver

Reproductive tract - for reproductive physiologists

TISSUE STATUS:

Tissue Taken for Trimming

Tissue Samples Ultrafrozen

Tissues ultrafrozen: body, liver, kidney, and lung.

SPECIAL REQUESTS:

Save carcass for DZR, contact Frank Kohn, 673-4753. Please follow specific guidelines for kangaroo rat post mortem. Save kidney, etc. per protocol.

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Path #: 91-572

RAT, MORRO BAY KANGAROO, DIPODOMYS HEERMANNI MORROENSIS

M-RODENTIA,

Path #: 91-572

Acc #: 109821  
Acc Date: 11/19/90

Death #: 41489  
Death Date: 12/25/91  
Necropsy Date: 12/25/91

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Sex: M                      Age: 5Y 6M 4D                      Wt.: 52.200GM                      Stay: > 30 Days

Manner of Death: Found Dead                      Interval: < 24 HRS  
Tag/Band/Tattoo: 325/BLUE (RIGHT EAR)                      X-rayed: NO  
Location at Death: CLIMATE CTL. ROOM #3                      Disposition: CARCASS TO DZR  
Submitter: FRANK KOHN, DZR                      Prosector: SCHULMAN  
Owner/Animal Dept: DZR

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HISTORY AND CLINICAL OBSERVATIONS:

6-21-86 Birth date; captive born at San Simeon.  
11-19-91 Loaned from USDI Fish and Wildlife Service.  
12-20-91 Weight - 60 gm, eating well.  
12-23-91 Weight - 58.4 gms, still eating.  
12-25-91 Found dead in nest box. Weight - 52.3 gm.  
Measurements: H - R = 136 mm  
Tail = 175 mm  
Rt. Rear Foot = 43 mm  
Girth = 85 mm

GROSS DESCRIPTION:

This adult, male Morro Bay Kangaroo Rat is in fair nutritional condition based on a minimal amount of subcutaneous and body cavity fat. All body orifices are patent and the teeth are evenly worn. There are no gross external lesions. There is a transducer in the right pinna and a healed laceration on the lateral margin of the left pinna. There are no gross lesions of the musculoskeletal or cardiovascular systems. The lungs are diffusely congested and have multiple pinpoint to 0.1 cm diameter, tan parenchymal foci (pneumoconiosis). The liver is tan-brown and tan mottled; firmer than normal; and slightly enlarged. The stomach contains a moderate amount of green, creamy material. The intestines contain a small amount of normal ingesta. The cecum contains a moderate amount of green, creamy material and the colon contains a small amount of normal, green fecal pellets. There are no gross lesions of the thyroid, adrenal glands, spleen, pancreas or testicles and epididymis. The kidneys are diffusely tan-pink but otherwise unremarkable. The urinary bladder is empty. There are no gross lesions of the brain or eyes.

SPECIAL REQUESTS:

Freeze one kidney (at -70 degrees C); place one testis, epididymis and vas

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Path #: 91-572

deferens, or ovaries on a saline moistened gauze pad in a covered petri dish and hold in refrigerator for Bill Rall (DAH, 673-4793).

FINAL DIAGNOSES:

- 1) MENINGES, MENINGITIS, ACUTE, MULTIFOCAL, MILD
- 2) LIVER, CIRRHOSIS
- 3) LIVER, HEPATITIS, ACUTE, FOCAL, MILD
- 4) KIDNEY, NEPHROPATHY, DIFFUSE, MILD
- 5) LUNG, ANTHRACOSILICOSIS, MODERATE
- 6) LIVER, HEMOSIDEROSIS, MODERATE

CAUSE OF DEATH:

DIGESTIVE, HEPATIC CIRRHOSIS

REMARKS:

This aged male kangaroo rat had multiple age-related lesions, the most severe of which was hepatic cirrhosis. The nephropathy was mild compared to the kidney changes seen in a younger male kangaroo rat autopsied this year (case 91-394). Pulmonary anthracosilicosis is a common finding in kangaroo rats. The acute hepatitis and meningitides seen histologically coupled with pure Pseudomonas aeruginosa cultured from the liver (CP #91-5184) are suggestive of a terminal septicemia. Hepatic cytology supports histologic findings (CP# 91-5185).

SCHULMAN

Prosecutor

NICHOLS

Pathologist

04/15/92

Date Completed

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Path #: 92-225

RAT, MORRO BAY KANGAROO, DIPODOMYS HEERMANNI MORROENSIS

M-RODENTIA,

Path #: 92-225

Acc #: 109824  
Acc Date: 11/19/90

Death #: 41734  
Death Date: 05/14/92  
Necropsy Date: 05/14/92

Sex: F                      Age: 5Y 11M 1D                      Wt.: 65.100GM                      Stay: > 30 Days

Manner of Death: Found Dead                      Interval: < 24 HRS  
Tag/Band/Tattoo: 326/326 (LEFT EAR)/                      X-rayed: YES  
Location at Death: MARMOSET BLDG.                      Disposition: SAVE FOR DZR  
Submittor: FRANK KOHN, DZR                      Prosector: SCHULMAN  
Owner/Animal Dept: DZR

HISTORY AND CLINICAL OBSERVATIONS:

6-13-86    Captive born - San Simeon.  
11-19-90    Loaned from USDI Fish and Wildlife Service.  
5-14-92    Found dead in cage; history of irritated left eye; weight averaged  
            around 65 - 70 gms.

GROSS DESCRIPTION:

This aged, female Morro Bay Kangaroo Rat is in poor nutritional condition based on lack of grossly detectable subcutaneous and body cavity fat. All body orifices are patent. There is a small notch in the lateral margin of the left pinna. There are no gross abnormalities of the pelage. The left mandibular lymph node measures approximately 2 x 1.5 x 0.8 cm, is red and tan-orange mottled, and extremely soft. There are no gross lesions of the cardiovascular system. There is approximately 1 ml of serosanguineous fluid within the pleural cavities. The lungs are diffusely hyperemic and slightly consolidated, however, they float in formalin. There are multifocal, pinpoint to 0.1 cm diameter, tan-green foci throughout the lung parenchyma (silicosis). The liver is red-brown and tan-orange mottled with a slightly rounded right middle liver lobe. The spleen measures approximately 1 x 0.2 x 0.1 cm and is tan-pink. There are no gross lesions of the pancreas, thyroid or adrenal glands. The kidneys are red-brown with granular capsular surfaces. The empty urinary bladder is grossly unremarkable. There is an approximately 0.2 cm diameter paraovarian cyst filled with clear, watery fluid, otherwise there are no gross lesions of the reproductive tract. The stomach contains a small amount of tan-white, creamy ingesta. The intestines contain a small to moderate amount of normal ingesta. There are no gross lesions of the eyes or brain. The bone marrow is tan-pink.

SPECIAL REQUESTS:

Save carcass for DZR, contact Frank Kohn (673-4753). Follow detailed procedure

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Path #: 92-225

for Morro Bay Kangaroo Rat (contact Bill Rall).

FINAL DIAGNOSES:

- 1) TUMOR, LYMPH NODE, MANDIBULAR, MASTOCYTOMA
- 2) KIDNEY, FIBROSIS, MULTIFOCAL, MILD
- 3) LIVER, FIBROSIS, MULTIFOCAL, MODERATE
- 4) LUNG, HEMORRHAGE, MULTIFOCAL
- 5) LUNG, CONGESTION, PASSIVE, CHRONIC
- 6) LUNG, ANTHRACOSILICOSIS, MODERATE
- 7) HEART, FIBROSIS, MILD
- 8) SYNDROME, INANITION
- 9) OVARY, CYST
- 10) THORACIC CAVITY, EFFUSION

CAUSE OF DEATH:

TUMOR, LYMPH NODE, MANDIBULAR, MASTOCYTOMA

REMARKS:

This kangaroo rat had a cervical cutaneous mast cell tumor surgically removed in April of 1991 (see X-4797); thirteen months later metastasis of this neoplasm to the mandibular lymph node resulted in inanition, possibly circulatory compromise and death. Cardiac, renal and hepatic fibrosis are not uncommon findings in aged rats. Cytology of the mandibular lymph node supported the diagnosis of mast cell tumor; however, while many mast cells were seen in imprints of the liver, they were not seen on histology of the liver (CP #92-1753, -1754). No bacteria were isolated from heart blood (CP #92-1752).

SCHULMAN

Prosector

NICHOLS

Pathologist

06/22/92

Date Completed

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Path #: 91-523

RAT, LOMPOC KANGAROO, DIPODOMYS HEERMANNI ARENAE

M-RODENTIA, HETEROMYIDAE

Path #: 91-523

Acc #: 110030  
Acc Date: 04/10/91

Death #: 41441  
Death Date: 11/29/91  
Necropsy Date: 11/27/91

Sex: M                      Age: 1Y +                      Wt.: 63.600GM                      Stay: > 30 Days

Manner of Death: Found Dead                      Interval: < 2 HRS.  
Tag/Band/Tattoo: 5                      X-rayed: NO  
Location at Death: CLIMATE CNTRL RM #3                      Disposition: SAVE CARCASS FOR DZR  
Submittor: FRANK KOHN, DZR                      Prosector: NICHOLS  
Owner/Animal Dept: DZR

HISTORY AND CLINICAL OBSERVATIONS:

11-29-91 Found dead, lying on his right side on cage floor - outside his nest box. Weight - 64.0 gms.  
Measurements: Head to Rump - 137 cm  
Tail - 155 cm  
Right Foot - 40 cm  
Right Ear - 10 cm  
Girth - 81 cm

GROSS DESCRIPTION:

The body of this adult, male Kangaroo Rat is in a fair nutritional condition. Subcutaneous fat stores are scant and abdominal fat is present in small amounts. The carcass is moderately autolyzed. The skin, pelage, body orifices and musculoskeletal system are within normal limits. The lungs are diffusely congested. The trachea, heart, esophagus, tongue and salivary glands are unremarkable. The liver, pancreas, spleen and gastrointestinal tract are in an advanced state of autolysis. The stomach and small intestines contain a small amount of mucoid material. The cecum contains a moderate amount of digesta. The colon is empty. The left testicle is present within the scrotum; the right testicle is intraabdominal, but otherwise unremarkable. The brain and eyes are autolyzed but otherwise unremarkable. The brain weighs 1.4 gms and the left eye weighs 0.2 gms.

SPECIAL REQUESTS:

Save carcass for DZR, contact Frank Kohn, 673-4753. Follow posted protocol for proceeding dead Kangaroo rats.

FINAL DIAGNOSES:

- 1) LIVER, HEPATITIS, NECROTIZING, ACUTE, FOCAL
- 2) LUNG, PNEUMONIA, INTERSTITIAL, MILD, FOCAL

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Path #: 91-523

CAUSE OF DEATH:

INFECTIOUS, BACTERIAL, PSEUDOMONAS AERUGINOSA

REMARKS:

This kangaroo rat had acute bacterial hepatitis with secondary pneumonia. Pure cultures of Pseudomonas aeruginosa were isolated from the heart blood and lung (CP #91-4910 and -4911).

NICHOLS

Prosecutor

NICHOLS

Pathologist

02/24/92

Date Completed