History of Research on Non-Native Fallow and Axis Deer at Point Reyes National Seashore and Golden Gate National Recreation Area

Monitoring of non-native deer in the Seashore began after all rancher hunting was discontinued in 1971. The research that followed can be divided into three categories: population, disease, and ecological studies. All publications and unpublished reports are described in the References section.

Population Studies

1972–1973: Wehausen (1973) studied fallow deer demographics and natural history. Through field observations he concluded the 1973 population was 479 and was below carrying capacity levels. He also concluded that the population was increasing at 11% per year (NPS 1984). Elliott (1973) used field observations of axis deer during the same year to conclude that the axis deer population of 401 was also below carrying capacity. He concluded the population was increasing at 22% per year. The main reason for the difference in herd growth rates for the two species was thought to be the age of first breeding, approximately 6 months earlier in axis than in fallow females (Elliott 1973).

1974: California Department of Fish and Game deer collections yielded estimates of population growth rates of 18% and 14.5% per year for fallow and axis deer, respectively. Such high growth rates were thought to be irruptive in nature and the result of a cessation of all hunting in 1972 (Brunetti 1974). Minimum population estimates, based on area ground counts in 1973–1974, were 600 fallow deer and 620 axis deer. Stabilization of both populations at these levels would require yearly removal of 360–420 animals (Brunetti 1975).

1975–1976: Elliott (1976a, 1976b) surveyed axis and fallow deer from the ground and by helicopter during the fall and winter of 1975–1976. He found a minimum of 492 fallow deer and 461 axis deer.

1977: Elliott (1977b) conducted a census of the entire Seashore by helicopter and with area counts and found a minimum of 523 fallow deer and 364 axis deer. He concluded that the deer control program at the time was effective in limiting only the axis deer to the target of 350 per species.

1979: Nystrom and Stone (1979) counted axis deer from the ground and estimated a total Seashore population of approximately 253 with an estimated 25% annual rate of increase.

1980–1982: A line transect census method was attempted but failed to adequately count exotic deer in the pastoral zone (Thompson 1981). Line transect censusing of fallow deer in the southern wilderness zone suggested higher densities of fallow deer (52.6 per square mile or 20 per square kilometer) than previously recorded there (Gogan et al. 1986).

1985: Ground censuses in the pastoral zone were conducted and total numbers of axis deer in the park were estimated to be 328. Fallow deer numbers, in the pastoral zone only, were estimated to be 114 (Ranlett 1985).

2001: Gogan et al. (2001) reviewed PRNS and CDFG data from 1976 through 1980 on non-native deer collections. Based on this data and on the published literature, a population model was developed to predict deer numbers with and without lethal removals. A carrying capacity of 455 for axis deer and 775 for fallow deer was postulated. Researchers concluded that axis deer are relatively vulnerable to eradication by ground shooting. Other conclusions were that NPS control of 1,873 fallow deer from 1968 to 1996 was unsuccessful in reducing numbers to less than 350 and that cessation of control would result in return of both populations to carrying capacity within 13 years (Gogan et al. 2001).

2000–2002: Concurrent helicopter and ground censuses were conducted throughout the Seashore (NPS 2001, 2002a). Minimum estimates of total populations were 475 and 623 for fallow deer in 2001 and 2002 respectively. Using a double survey method in 2002, in which ground and aerial censuses were conducted concurrently, the total fallow population size was estimated to be 771 with a 95% Confidence Interval of 636 to 2,272 animals. Fawn/doe ratios, similar to those of the 1970s, indicated that the fallow population might be below carrying capacity and might continue to increase. Fallow deer densities ranged from 0 to 210 deer per square mile (up to 81 deer per square kilometer) in different parts of the Seashore. Minimum estimates for axis deer were 211 and 229 in 2001 and 2002 respectively and were considered to approximate real population numbers.

Also in 2001, Barrett created a population model based on his previous modeling work in Gogan et al. (2001). In the new model, the effects of yearly contraception in fallow deer could be predicted (Barrett unpublished report 2001). Using the same assumptions of age and sex dependent mortality rates and the same carrying capacity as in Gogan et al. (2001), it was estimated that stabilization of fallow deer populations at 350 could only occur with contraception of approximately 80% of all does of reproductive age with a contraceptive that was 100% effective. Eradication of fallow deer from the Seashore and GGNRA lands by 2050 would require yearly contraception of 99% of all fallow does of reproductive age with a contraceptive that was 100% effective (Barrett unpublished report 2001).

2002–2003: During the winter of 2002–2003, NPS and USGS researchers conducted a mark-resight study of fallow deer at PRNS, using 29 radio-collared deer to evaluate the proportion of animals missed on aerial censuses. The study resulted in an estimate of 859 fallow deer (90% Confidence Interval = 547 - 1170) (PRNS unpublished data (f)). A ground count of axis deer by NPS staff in May 2003, resulted in an estimated population size of 230–250 animals and an observed fawn/doe ratio of 1 fawn for every 3 adult does (NPS 2003).

Also in 2003, Hobbs created a stage-based simulation model to examine the effects of culling and fertility control on fallow deer numbers in PRNS (Hobbs 2003). Using similar assumptions as Gogan et al. (2001), and assuming that density dependence in the population causes a linear decrease in herd growth as it approached a carrying capacity of 1000 animals, Hobbs found that:

- Attempting to eradicate the population in 15 years, using only fertility control (either yearly contraception or longer duration agents), would be futile.

- Approximately 620 fallow does would need to be culled to eradicate the population in 15 years, in the absence of any fertility control.

- Treating animals with contraceptives that are effective for at least 4 years with one dose could reduce the number of animals that would need to be culled in order to eradicate the population.

- Fertility control would not reduce the total number of animals that would need to be handled (either treated or culled).

For a detailed explanation of the assumptions and conclusions of the Barrett and Hobbs population models, see Appendixes B and D.

TABLE 4: SUMMARY OF EXOTIC DEER POPULATION ESTIMATES FROM INTRODUCTION TO 2003

Year	Fallow Deer Numbers	Axis Deer Numbers	Reference
1942 (first introduction of fallow deer)	15		Wehausen 1973
1947 (first introduction of axis deer)	11	4	Elliott 1973, San Francisco Zoo unpublished records
1948		4	San Francisco Zoo unpublished records
1954	2		San Francisco Zoo unpublished records
1973	479		Wehausen 1973
1973		401	Elliott 1973
1974	600*	620*	Brunetti 1975
1976	492*	461*	Elliott 1976a, 1976b
1977	523*	364*	Elliott 1977b
1979		253	Nystrom and Stone 1979
1985		328	Ranlett 1985
2001	475*	211	NPS 2001
2002	623*	229	NPS 2002a
2003	859	230–250	Unpublished PRNS data (f); NPS 2003

* These are minimum counts. True numbers are likely higher.

Disease Studies

1974–1975: During this time, California Department of Fish and Game (CDFG), with assistance from NPS, collected a total of 290 native and non-native deer and performed complete necropsies (Brunetti 1976). The primary purpose of the study was to determine population dynamics, forage habits, and disease prevalence. A secondary purpose of the study was to directly reduce non-native deer numbers. Serological testing in fallow deer showed high exposure to livestock diseases such as bovine viral diarrhea and infectious bovine rhinotracheitis. On necropsy, 54.2% of fallow deer carried liver flukes. A low incidence of lungworm and intestinal parasites were found in both species. CDFG researchers concluded that both populations were relatively healthy and in good condition (Brunetti 1976).

1976–1977: Researchers analyzed serological titers and kidney fat indices (an indication of body condition) on 150 native and exotic deer collected by NPS and CDFG (Elliott 1977a; Riemann et al. 1979a). As in previous studies, they found that the non-native deer were in good physical condition but found evidence of exposure to: bluetongue, Q fever, infectious bovine rhinotracheitis, bovine viral diarrhea, anaplasmosis, toxoplasmosis, leptospirosis, and parainfluenza 3 (Elliott 1977a; Riemann et al. 1979a). Another study on paratuberculosis, or Johne's disease, was conducted with the same collected deer and on cows from 10 dairy herds in and around the Seashore. The causative organism for Johne's disease was found in 8.1% of fallow deer, 9.6% of axis deer, and 8.7% of cows tested (Riemann et al. 1979b).

2000: NPS biologists culled 7 axis deer and 9 fallow deer for disease testing (NPS unpublished data (g)). Lung and intestinal parasites were found and serology showed exposure to anaplasmosis and leptospirosis in one axis and one fallow deer, respectively. One axis deer tested positive for Johne's disease.

2005**:** USDA researchers culled 7 fallow deer and 5 axis deer for a comprehensive survey of ectoparasites occurring on non-native deer ectoparasites. *Bovicola tibialis*, an exotic chewing louse typical of fallow deer, was found on PRNS fallow deer. USDA researchers believe this parasite could transfer from PRNS fallow deer to native elk and black-tailed deer and potentially cause disease in the native cervids (J. Mortensen, USDA, personal communication). *B. tibialis* has been found in a population of symptomatic black-tailed deer in British Columbia during the 1940s (Bildfell et al. 2004) and in large numbers on captive black-tailed deer in Mendocino County, CA, in the 1970s (Westrom et al. 1976). Introduced fallow deer were associated with both of these incidences on black-tailed deer. More recently, *B. tibialis*, evidently originating from local fallow deer, has been found on wild mule deer in poor condition in Washington State (Bildfell et al. 2004; J. Mertins, USDA, personal communication). There is a considerable likelihood of this parasite being responsible for the documented pathology in Canadian and US black-tailed deer (J. Mertins, USDA, personal communication).

Another chewing louse, *Damalinia (Cervicola) forficula*, was found on PRNS axis deer. *D.c. forficula*'s native typical hosts are axis and hog deer and they have been documented in the deer's native range (India, Indochina, Nepal, Pakistan, and Sri Lanka). These lice have never before been identified in North America, and the risks they pose to native deer are unknown.

Finally, *Damalinia (Tricholipeurus) odocoilei*, a chewing louse native typically found on native black-tailed deer, was found on a PRNS fallow deer. Again, the likelihood of this parasite causing disease in either black-tailed, fallow or axis deer is unknown, but it is not usually pathogenic to black-tailed deer.

Ecological Studies

1973–1974: Collection and necropsy of 290 native and non-native deer by California Department of Fish and Game yielded information on food habits. The primary food item for both axis and fallow deer was found to be similar to that of elk and consisted of grass with some use of forbs (Brunetti 1974 and 1975).

1976–1979: Growing concern from ranchers within the park's pastoral zone regarding forage competition between exotic deer and livestock prompted studies on dietary overlap (Elliott 1982; Elliott and Barrett 1985; Wehausen and Elliott 1982). Data were collected in the western and southern portions of the deer ranges but not in the Olema Valley or PRNS-administered GGNRA lands. These studies revealed some dietary overlap between non-native deer and both cows and native black-tailed deer, especially during times of low forage availability. Diets of exotic deer consisted mainly of grasses and forbs and overlapped more with each other than with black-tailed deer except in summer when forbs were an important part of all deer diets. Both exotic and native deer had diets deficient in energy from May through October (Elliott 1982). Elliott and Wehausen found that both axis and fallow deer preferred areas used by livestock (Wehausen and Elliott 1982). Habitat preferences of all three deer species in the pastoral zone were similar, namely, open grassland. Because of insufficient sample size, Elliott could not detect statistically significant effects of non-native deer on black-tailed deer fawn production or survival. He suggested that densities of exotic deer present in 1973 ($\leq$17 deer / sq. km. or 350 of each species) would not negatively affect the density of black-tailed deer (Elliott 1982).

1983: A review of Elliott's 1982 dietary overlap study by Gary Fellers, a U.S. Geological Survey scientist, suggested that exotic deer at levels of 350 for each species could reduce the native black-tailed deer population size by up to 30%. If native deer numbers are strongly influenced by the energy content of their diet, the reduction in their population could be as much as 40% below carrying capacity (Fellers 1983). Recently, further analysis of Elliott's data by Fellers (Fellers 2006) has indicated that the impacts of non-native deer on native black-tailed deer may be more significant than previously thought. At currently estimated population levels for all three species, and during seasons of low forage availability, such as summer, for every 1-2 axis or fallow deer present in the Seashore, one black-tailed deer is lost.

2000: Diets of fallow deer and tule elk were compared in 2000-2001 (Fallon-McKnight 2006). The researchers found that elk and fallow deer in the Limantour area used similar forage species throughout the year. The study concluded (p. 5) that: "Fallow deer, present at Limantour but not at Tomales Point, may impact sympatric elk at the Limantour site in their foraging for *Plantago* spp. (a high energy and high protein forage). Competition for forbs likely remains throughout spring and summer, which is a time that both species are nursing young. This hypothesis requires further testing. Increased grazing pressure on this and other important forage items by fallow deer could potentially deprive Limantour elk of the nutritional benefits of these food resources at a critical time."

2006: USGS researchers studied the impacts of fallow bucks on riparian and woodland soils and vegetation during the breeding season or rut (Fellers and Osbourn 2006). Unlike other cervids, fallow deer form "leks", traditional mating territories revisited yearly and defended by bucks. Researchers sampled two areas within the fallow deer range, the Bear Valley area of Olema Valley, and the Estero trail, and documented a total of 159 leks (see map, Figure 12). The leks were recognizable as areas of bare ground with excavated pits and consisting of compacted, disturbed soils. Leks were up to 32 meters across and included as many as 30 individual pits. The disturbance resembled that of feral pigs, however the soils appeared more compacted than tilled. Over 700 scraped out pits, averaging 2.5 square meters across and up to 0.6 meters deep, were documented in the two areas studied. Vegetation damage included complete removal of understory plants, shredded foliage, damaged tree bark, broken tree branches, exposed roots, and girdling of young trees and saplings. The density of leks in the Estero Trail and Bear Valley area was 28.4 and 78.8 per square kilometer respectively. In Bear Valley, over 1% of the total land area surveyed was impacted with lek damage and riparian areas were disproportionately affected. USGS researchers concluded that fallow deer are having a significant impact on the soils and vegetation in the Seashore. Lekking impacts are shown in Figures 13-16 (note: Figures 13-16 are photographs of fallow deer leks in Olema Valley, taken during the fall and winter of 2005 (Fellers and Osbourn 2006)).

FIGURE 12: MAP OF FALLOW DEER LEK SITES, BEAR VALLEY AREA, POINT REYES NATIONAL SEASHORE (EACH POINT REPRESENTS ONE LEK, COMPRISED OF UP TO 30 EXCAVATED PITS AND AVERAGING 115 SQUARE METERS.) (FELLERS AND OSBOURN, 2006)

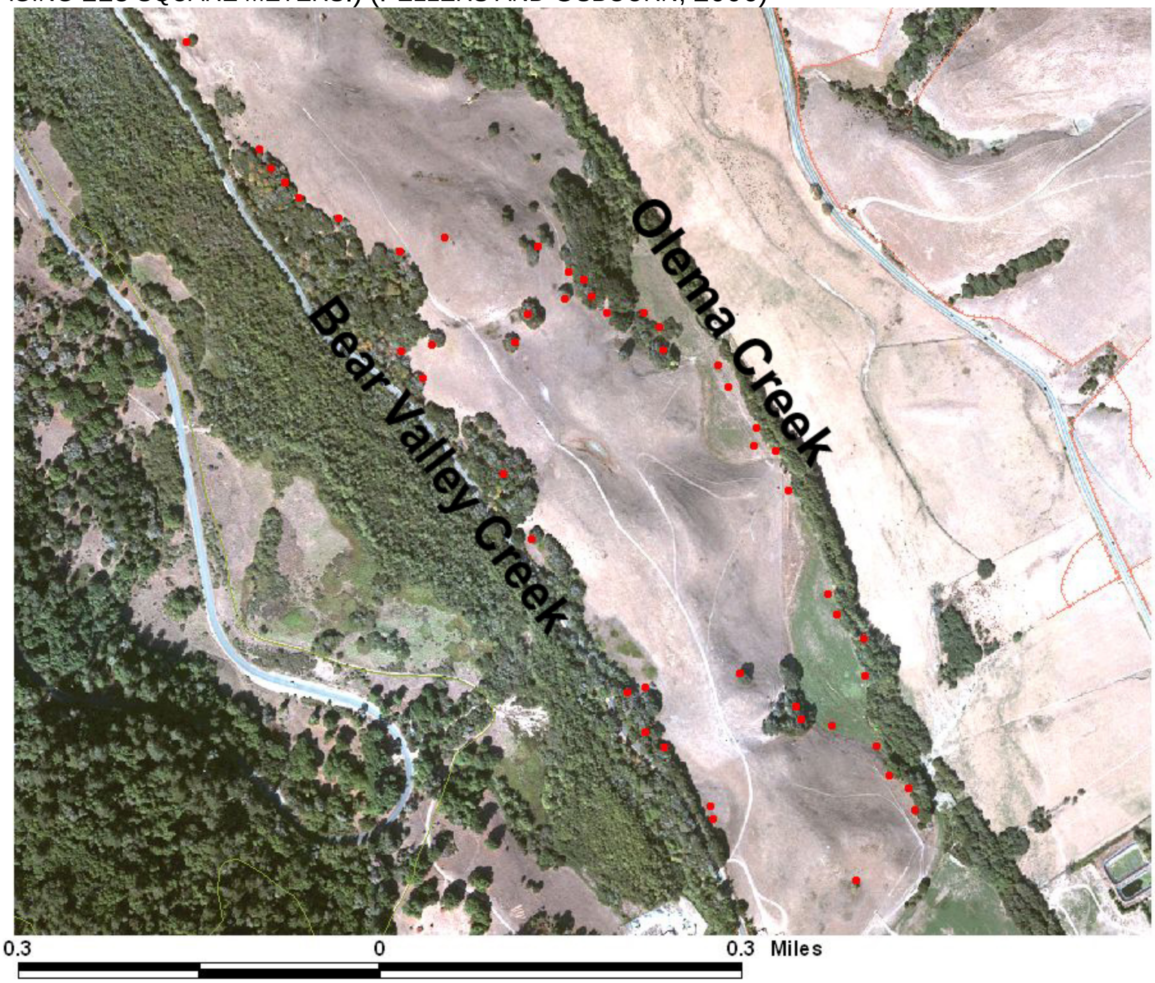

FIGURE 13: BARK DAMAGE (GIRDLING) OF SAPLING DOUGLAS FIR IN A LEK

FIGURE 14: EXCAVATED PIT WITHIN A LEK

FIGURE 15: FALLOW BUCK ON SMALL LEK

FIGURE 16: DISTURBED SOIL AND DENUDED VEGETATION AT LEK SITE, OAK WOODLAND-PASTURE INTERFACE

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Species and Habitats of Management Concern

The U.S. Fish and Wildlife Service (USFWS) and/or the State of California list many of the plant and wildlife species, and habitats present in the project area. The Marine Mammal Protection Act and the Migratory Bird Treaty Act afford additional protection.

Species of Management Concern

The study area supports 47 listed animal species – 14 are federally listed as endangered, 8 as threatened, and 24 as Species of Concern. Among these listed species are the endangered brown pelican (*Pelecanus occidentalis*) and Myrtle's silverspot butterfly (*Speyeria zerene myrtleae*). Federally threatened species include Northern spotted owl (*Strix occidentalis caurina*), Western snowy plover (*Charadrius alexandrinus nivosus*), and red-legged frog (*Rana aurora draytoni*). Nineteen federally listed plant species (seven of which also are state listed) and an additional 25 species are listed or proposed for listing by the California Native Plant Society and have been documented in the study area**.** For purposes of this document, all of these species are considered as "Species of Management Concern." The Species of Management Concern that may be affected by implementation of the Non-Native Deer Management Plan are discussed below.