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Robert N. Lea, Ph.D., Editor-in-Chief
California Fish and Game
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POPULATION CHARACTERISTICS OF WILD PIGS, *SUS SCROFA*, IN EASTERN SANTA CLARA COUNTY, CALIFORNIA [1]

MARTHA E. SCHAUSS [2]
Department of Biological Sciences,
San Jose State University,
San Jose, CA 95192

HENRY J. COLETTO [3]
Santa Clara County Parks and Recreation Department
298 Garden Hill Dr.
Los Gatos, CA 95030

and

MICHAEL J. KUTILEK
Department of Biological Sciences
San Jose State University
San Jose, CA 95192

Wild pigs were studied in Grant County Park in central California between 1978 and 1980. A population density estimate in 1978 was 3.2–4.7 pigs/km^2 (95% confidence limits), with a decrease of 51% in 1979 and an increase of 65% over 1979 in 1980. Changes in density corresponded to variations in acorn production and juvenile recruitment. Hunters outside of the park killed 18% of the pigs tagged in the park. Predation upon juveniles by native predators was facilitated by eye damage from foxtails incurred by the pigs. Fifty-nine percent of the pigs tested were positive for *Coxiella burnetti*, and 10% for *Trichnella spiralis*. High levels of *Ascaris suum* ova and *Eimeria* sp. oocysts were found in fecal samples. From analysis of fecal samples, grasses and forbs were important in the summer diet, with an increase in mast and acorns in the fall. Roots and bulbs were the primary food items in winter and spring samples.

INTRODUCTION

European wild boar, *Sus scrofa,* were introduced into the Monterey area of California from North Carolina in the 1920's (Pine and Gerdes 1973). They have since hybridized with feral pigs and spread throughout the State. Relocation of wild pigs by private landowners has resulted in establishment of pig populations in 33 of California's 58 counties (T. Mansfield, pers. comm.). Although popular game animals, wild pigs can damage agricultural crops, springs, pastureland, and native flora and fauna and can disturb camping and picnic areas in parklands (Pine and Gerdes 1973, Bratton 1977, Barrett and Pine 1980, Singer et al. 1984).

In California, wild boar-feral hog hybrid densities have been estimated in chaparral-woodland habitat in Monterey County (Pine and Gerdes 1973) and on Santa Catalina Island (Baber and Coblentz 1986). Feral hog densities have been estimated in Tehama County oak woodland (Barrett 1978). Barrett (1978) estimated that pigs may have a negative impact on livestock production at densities higher than about 6 pigs/km^2 on wooded land, or 0.4–0.8 pigs/km^2 on

[1] Accepted for publication January 1990.
[2] Present address: P.O. Box 1991, Gilroy, CA
[3] Present address: Santa Clara Co. Sheriff's Dept.

most of California's rangeland. On both public and private property, the extent of damage caused by wild pigs depends on land use and pig density.

The purpose of this study was to estimate population density, age structure, sex ratio, and mortality factors of wild boar-feral pig hybrids in an unhunted county park in central California. Home ranges, movement patterns, and physical characteristics have been described by Schauss (1980). Because fall acorn availability has been cited as a key factor in wild pig survival and reproduction (Matschke 1964, Conley 1977, Barrett 1978), we assessed acorn production and pig diet during the study period. The results are presented to help understand the role of wild pigs in public recreation areas and to anticipate and manage pig-related problems.

STUDY AREA AND METHODS

The study site was the 38.6 km^2 Grant County Park in the Mt. Hamilton region of the Diablo Range east of San Jose, California. The region has a Mediterranean climate with mean temperatures of 6.4 °C in January and 23.9 °C in July. Annual rainfall during the study period averaged 57 cm with about 80% of it falling between January and March.

The vegetation is a mosaic of grassland and oak woodland with patches of poison oak, *Toxicodendron diversiloba*, coyote bush, *Baccharis pilularis*, and California sage, *Artemisia californica* (Heady 1977). Year-round water sources include springs and stockponds located throughout the park, and two freshwater marshes.

The park is used for hiking, horseback-riding and camping. Year-round cattle grazing occurs throughout most of the area. Hunting is not permitted in the park, but surrounding landowners hunt both pigs and black-tailed deer, *Odocoileus hemionus columbianus*.

We trapped pigs from May 1978 through August 1979, and June through August 1980. Animals were captured in cage-type traps in areas where pig activity was evident.

Each pig was ear-tagged, weighed, and the sex and physical condition were noted. Age was estimated by tooth eruption and wear (Matschke 1967). We removed a third lower incisor from mature adults for cementum layer analysis (Laws 1952). Longitudinal tooth sections were prepared using the method described by Frost (1958).

We calculated a population estimate for 1978 using the Lincoln Index by considering 1978 to be the marking period and 1979 the recapture period. We did not include pigs born after the beginning of the first trapping period for this estimate.

A second density estimate was made using a method presented by Edwards and Eberhardt (1967). This population estimator includes compensation for differences in catchability within a population, based on a geometric distribution of capture frequency. To calculate this estimate, we lumped captures into 4-week periods so that not more than 1 capture was counted for any pig during each 4-week trapping period.

We made a third population estimate by applying the Lincoln Index to the proportion of tagged pigs sighted in the study area between November 1978 and January 1979.

We collected fecal samples by rectal examination. Samples were examined by the California Department of Fish and Game's (CDFG) pathology laboratory for the presence of endoparasite ova. We stored a portion of each fecal sample in 10% formalin for diet analysis. The percent volume of identifiable material was estimated visually.

Blood samples were tested for selected pathogens by the CDFG, the California Department of Food and Agriculture, and the University of California, Davis.

We estimated acorn production of valley oak, *Quercus lobata,* black oak, *Q. kelloggii,* blue oak, *Q. douglasii,* and coast live oak, *Q. agrifolia,* in the fall of each year, using a CDFG method (Graves 1979). Randomly selected trees of each species were given a rating of 1 (zero acorns) to 4 (abundant acorns) based on visual estimates of acorn abundance. Acorn data for the Mt. Hamilton Range for the fall previous to our field work were obtained from CDFG records.

RESULTS

We tagged and released 138 pigs, with a total of 556 captures. 59% of adult females (older than 1 year), 52% of adult males, and 54% of juveniles were recaptured at least once. The number of captures/animal was higher for adult females than for adult males, and was higher for juveniles of both sexes than for adults.

The Lincoln Index estimate derived from 1978 and 1979 trapping yielded a population estimate of 118 pigs, with an estimated density of 3.1 pigs/km^2 (95% confidence interval of 2.4–4.2 pigs/km^2). Observations of untagged animals indicated that this number was low, as would be expected by observed responses to trapping.

Using 4-week capture intervals, the mean number of captures/animal between May 1978 and August 1979 was 2.1. As per the Edwards-Eberhardt estimator, geometric regression of capture frequency yielded a population estimate of 138 for the spring of 1978, and a density estimate of 3.6 pigs/km^2.

The Lincoln Index estimate using 1978 trapping data and 1978–1979 sightings gave us an estimate of 148 pigs, with a density of 3.8 pigs/km^2 (95% confidence interval of 3.2–4.7 pigs/km^2) for 1978. For purposes of discussion and subsequent calculations, we will consider this to be the most accurate density estimate.

During the study period trapping success fluctuated greatly. The mean number of captures/trap-day declined from 7.3 in July 1978 to 0.6 in May 1979 (Figure 1). The variation was due in part to seasonal differences in trapability. The mean number of recaptures/captured animal was 2.2 in August 1978, and 0 in March 1979.

Another reason for the variation in trapping success was a decline in population density. The mean number of different pigs caught/trap-day for each month between May and August 1979 was only 49% of that for the same months the previous year. Applying a catch/unit-effort comparison, 49% of the 1978 density estimate gives an estimate of 1.9 pigs/km^2 for the spring of 1979. The mean number of animals caught/trap-day for each month between May and August 1980 increased by 65% over that in 1979. Comparing this to the 1978 capture, the density estimate for the spring of 1980 was 3.1 pigs/km^2.

The age structure of the trapped population revealed a high proportion of animals under 2 years old. 60% of the captured pigs were juveniles, and 25% were 1–2 years old. The ratio of juvenile pigs to adult females captured during the summer months was 3.3 in 1978, 1.4 in 1979, and 7.5 in 1980.

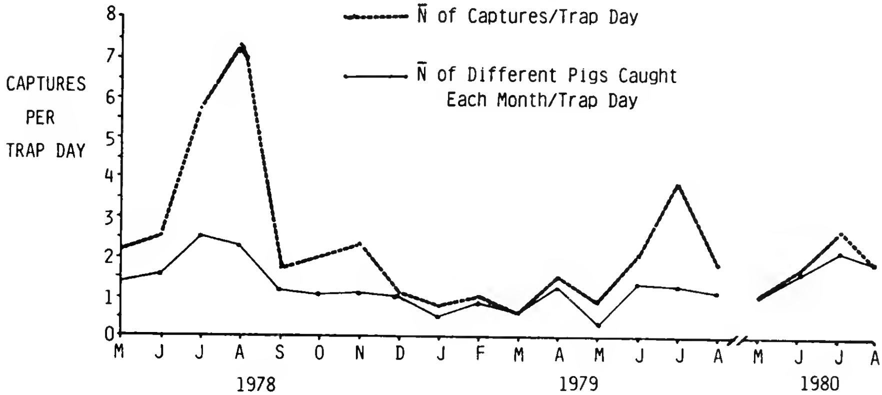

FIGURE 1. Mean number of wild pigs captured/trap-day and number of different pigs caught each month/trap-day for months between May 1978 and August 1979, and May through August 1980.

Survivorship curves for males and females from the combined 1978–1980 data approximate a log-linear relationship (Figure 2). Time specific life tables suggest that mortality rates for both sexes were highest during the second year of life (Table 1). However, pigs under 6 weeks old were seldom captured, so neo-natal mortality was not included in the first year's mortality rate. The lowest age specific mortalities and the greatest mean life expectancies were found in 2–3 year old animals of both sexes. Life expectancy was slightly higher for females than for males throughout life. The oldest pig captured was a 6–7 year old female. The oldest males caught were 4–5 years of age.

Hunters on private property returned tags from 18% (24) of the tagged pigs. Of these, 50% (12) were adult females, 21% (5) were adult males, and 29% (7) were juveniles. One tagged and two untagged juveniles were found that had apparently been killed by predators. Pig remains were also found in coyote, *Canis latrans*, scats as a result of either scavenging or predation.

About 40% (32) of the juveniles and several of the adults captured between June and September of each year had foxtails, *Hordeum* sp., in one or both eyes. Twenty-two percent (18) of the juveniles had corneal damage.

Blood tests showed low prevalence of *Leptospira pomona and L. icterohaemorrhagia* in the population. Of the pigs tested 59% (n=54) were positive for Q-fever rickettsia, *Coxiella burnetti*. Tests for *Trichnella spiralis* were positive for 10% and suspect for 18% (n=54). Results were negative for *Brucella abortus, L. canicola, Salmonella typhimurium, Taxoplasma gondii*, and viral agents of

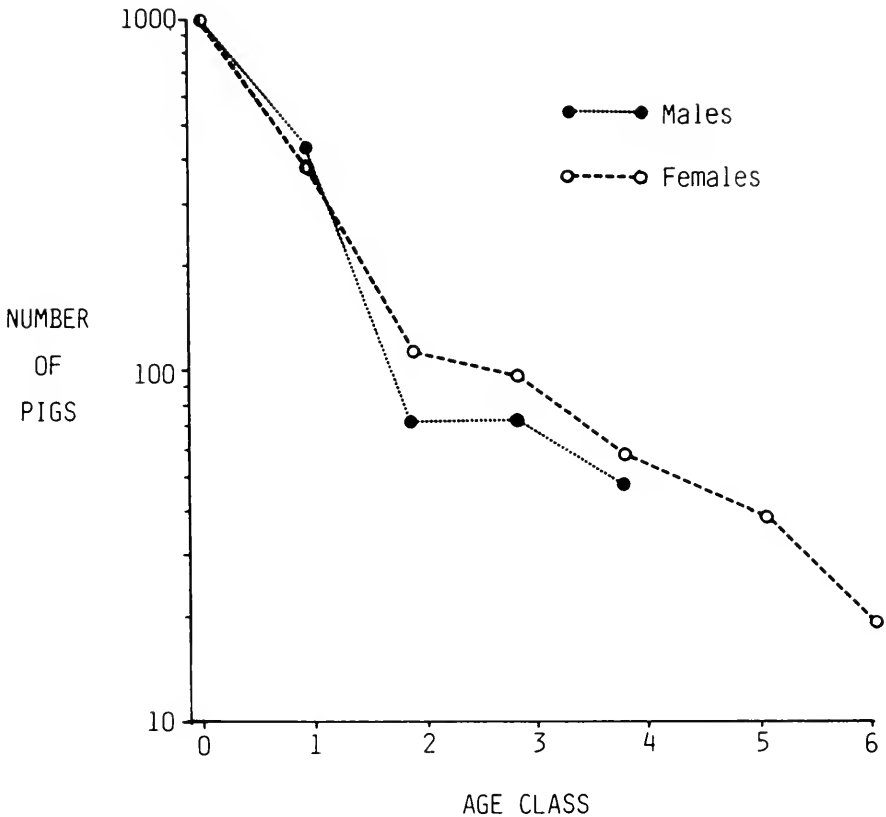

FIGURE 2. Survivorship curves for male and female wild pigs captured in Grant Park, 1978–1980.

African swine fever, bovine viral diarrhea, hog cholera, and swine vesicular disease. Ova of *Ascaris suum, Oesophagostomum* sp., *Ascarops strongylina, Metastrongylus apri, Stephanurus dentatus*, and a liver fluke, probably *Fasciola hepatica*, were found in fecal samples, as were oocysts of *Balantidium coli*, and *Eimeria* sp. Of these, *Ascaris suum* and *Eimeria* sp. were found in high levels, particularly in juveniles.

Acorn scores reported by the CDFG for 1977 showed fair productivity for black oaks, moderately poor for valley oaks, and poor for blue oaks (Figure 3). Data were not available for coast live oaks. Acorn production was very poor in 1978. For the 4 oak species, 89% of the trees counted had no acorns visible. On the rating scale of 1–4, all species rated below 1.5. In 1979 all species had improved acorn production. A mean of 54% of trees of the 4 species had acorns visible. Both valley and live oaks had mean scores above 2.0.

TABLE 1. Time Specific Life Tables for Male and Female Wild Pigs in Grant Park from 1978–1980 Capture Data.

A. Males

Age (Years)	No. Captured	1_x	d_x	q_x	e_x
0–1	42	1000.0	571.4	0.571	1.12
1–2	18	428.6	357.2	0.833	0.94
2–3	3	71.4	0.0	0.0	2.17
3–4	3	71.4	23.8	0.333	1.17
4–5	2	47.6	47.6	1.000	0.50

B. Females

Age (Years)	No. Captured	1_x	d_x	q_x	e_x
0–1	53	1000.0	604.0	0.604	1.22
1–2	21	396.0	292.9	0.740	1.31
2–3	6	113.1	18.9	0.167	2.33
3–4	5	94.2	37.7	0.400	1.70
4–5	3	56.6	18.8	0.333	1.50
5–6	2	37.7	18.9	0.500	1.00
6–7	1	18.9	18.9	1.000	0.50

x = Age
1_x = Number living at age x out of cohort of 1000
d_x = Number of deaths at age x out of cohort of 1000
q_x = Mortality rate (dx/1x)
e_x = Life expectancy at age x

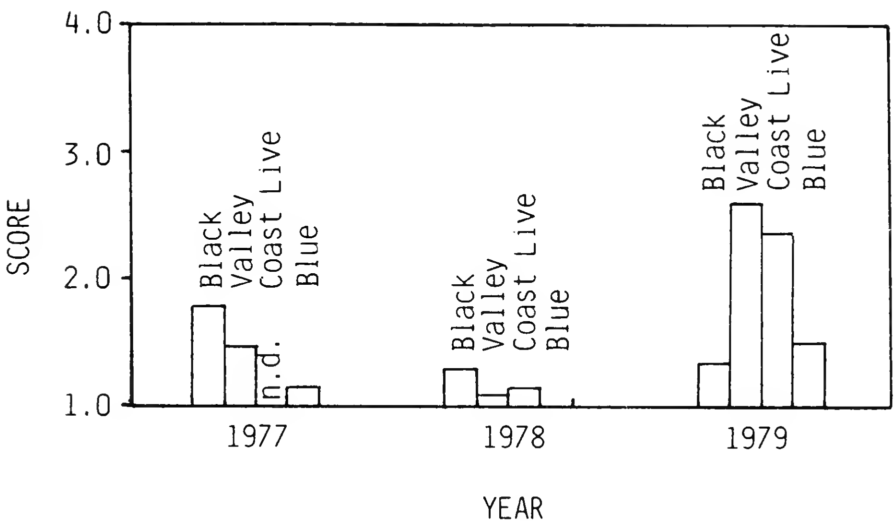

FIGURE 3. Estimated acorn production of four oak species in Mt. Hamilton area, 1977–1979.

Grasses and forbs comprised the major part of fecal samples collected in the summer of 1978, with small amounts of mast and roots present (Table 2). Fruit material identified was from holly-leafed cherry, *Prunus ilicifolia*, cherry plum, *Prunus* sp., and olive, *Olea* sp. Mast and roots increased in percent volume in the fall with a corresponding decline in grazed vegetation. As mast was depleted, the volume of roots and bulbs increased in winter and spring samples.

TABLE 2. Estimated Percent Volume and Percent Frequency of Occurrence of Materials in Fecal Samples Collected from Wild Pigs in Grant Park, 1978–1979.

	June–Aug 1978 n=63		*Sept–Oct 1978 n=11*		*Dec 1978–May 1979 n=8*		*June–Aug 1979 n=11*	
	%V	*%F*	*%V*	*%F*	*%V*	*%F*	*%V*	*%F*
Grass, sedge, forb	76	100	32	82	29	100	78	100
Mast hulls	7	25	34	100	2	13	2	27
Fruit skins, pits	1	13	0	0	3	13	7	27
Roots, bulbs	8	48	30	55	56	50	4	64
Insects	Tr.	6	0	0	Tr.	13	0	0
Debris	3	64	3	64	4	86	4	73
Unidentified vegetation	4	24	1	18	6	50	4	73

Rooted food items continued to be important as long as the soil was moist. By June, the amount of root material decreased, and the volume of grasses had increased. Traces of insects were found in fecal samples sporadically throughout the study period. Although no samples were found that contained vertebrate remains other than traces of pig hair, pigs and pig sign were observed near cow carcasses on several occasions.

DISCUSSION

The highest estimated density of pigs in our study area, 3.8 pigs/km^2 in May 1978, was intermediate compared to other areas in California. Pine and Gerdes (1973) reported a density of 0.5–0.8 pigs/km^2 in a chaparral-woodland area of Monterey County. Barrett (1978) calculated 5–8 feral hogs/km^2 on a private ranch in Tehama County where a portion of the population foraged on irrigated pasture. The highest densities reported were on Santa Catalina Island, with 23–34 pigs/km^2 (Baber and Coblentz 1986).

The diet estimates for Grant Park were based on fecal samples collected in a poor acorn year. The fall samples were similar to those reported by Barrett (1978) during poor acorn production in 1967 in Tehama County. In both areas the amount of mast material was lower, and root and bulb volume was higher than in good acorn years reported in the Tehama study, or in samples collected from pigs in Monterey, San Benito, and San Luis Obispo Counties (Pine and Gerdes 1969). We found higher volumes of roots and bulbs in our winter-spring samples and lower volumes of grasses and forbs than either the Tehama or Monterey County Studies. Pigs in this part of the Diablo Range apparently turned to grasses and forbs later in the year than the other areas, and these foods comprised the bulk of the summer samples. Grant Park has a comparatively large amount of riparian habitat which was utilized by pigs in the summer months, and may have provided more green forage than was available in the other study areas. However, as reported by both Barrett (1978) and Pine and Gerdes (1973), conditions were poorest in the summer. The 2 key factors in pigs' annual diet in all studies were the availability of summer forage and the abundance of acorns in the fall.

Mansfield (1978) reported that juveniles killed in a Monterey County public hunting area in October and November were lean and that fat levels of adults depended on the availability of acorns. In southeastern states, Matschke (1964) and Conley (1977), reported that in poor acorn years, winter pig mortality was high and reproduction was low the following year.

In the Diablo Range, the poor acorn production in the fall of 1978 was followed by a warm wet winter and spring. Pigs caught in the spring of 1979 were in good physical condition, but the number of juveniles caught/adult female decreased markedly from the summer of 1978 to the summer of 1979. Acorns were plentiful in 1979 and pig survival and reproduction were high. The ratio of juveniles to adult females reflected favorable conditions. The population decrease in 1979 and increase in 1980 may be linked to the previous falls' acorn production.

Several potential inaccuracies must be accepted when developing a time-specific life table from several years' trapping data, particularly with a population that shows annual fluctuations and nonrandom trapping response. The 2 years prior to this study were drought years, which may have resulted in high pig mortality. This would have increased the observed mortality rate between age classes 1 and 2 of the survivorship curve. The shape of the curve may also have been influenced by behavioral responses to trapping. Older males were more difficult to capture and may have escaped from traps more often than smaller pigs. This would have lowered the estimated mean life expectancy for males. Infant mortality was probably high before juveniles were captured, and mortality during the first year of life was probably higher than indicated. Nevertheless, we believe that the survivorship curves presented here are rough approximations of the age specific mortality schedules for the population. They are intermediate to those developed by Barrett (1978) for pigs that died from natural causes, and those killed by hunting in a Tehama County study. The pigs trapped in Grant Park had a life expectancy close to that of the hunted Tehama County population. Barrett estimated a mean life expectancy of 1.6 years at 6 months for hunter-killed pigs, and 4.3 years for pigs that died from natural causes.

Wild pigs have been reported to be an important prey species for mountain lions in this part of the Diablo Range (Smith 1981). Predation by mountain lions was a source of mortality seen for juvenile pigs in this study. Other potential piglet predators were coyotes, bobcats, *Lynx rufus* , and golden eagles, *Aquila chysaetos.* A major debilitating factor, particularly for juvenile pigs, was the occurrence of foxtails in the eyes, which may have increased susceptibility to infection and predation.

Coxiella burnetti, the only disease agent found in high levels in this population, is not a major factor in wildlife or livestock mortality, but may cause flu-like symptoms in man (Bell 1970). Occurring in a wide variety of mammalian hosts, reactors to *Coxiella* were found in 50% of pigs sampled in 4 locations in California between 1981 and 1983 (Clark et al. 1983). As in our study area, Clark et al. (1983) found pseudorabies to be absent in Santa Clara County samples, but found 3% of pigs sampled throughout the state to be positive for the pseudorabies virus. Where present, pseudorabies could be of importance to the livestock industry. *Leptospira* spp. can also cause livestock losses and *L. suis* can cause abortion in swine (Roth 1970). *L. pomona* and *L. icterohaemorrhagia* were tested for in this study and found in levels too low to be considered important.

Reactors to *Brucella abortus* were not found in this wild pig population. *B. abortus* was also absent in deer and cattle tested in Grant Park between 1981 and 1984 (Schauss and Coletto 1986). Clark et al. (1983) reported 15% positive reactors for *Brucella abortus* in wild pigs statewide, and 8% in Santa Clara County.

Trichella spiralis, disease agent of trichnosis, is of concern for humans handling or consuming pig meat (Zimmerman 1981). The occurrence of *Trichnella* in Grant Park indicates the importance of monitoring disease agents in wild pig populations and of careful handling of carcasses where pigs are killed by hunters.

Legal hunting does not occur within Grant Park, but was a significant mortality factor to the pig population. Hunting pressure was high on animals that moved onto private property to utilize cultivated food sources. Mansfield (1978) found that sows with litters were more active during daylight hours than were other pigs in the spring and summer. The higher nutritional requirements of lactating females and growing juveniles may prompt them to feed in higher risk situations, making them more subject to hunting mortality and more likely to come in conflict with human activity than other pigs.

In many areas of California where pigs are a serious nuisance, the density limiting effects of the summer dry period and poor forage are dampened by the availability of food on agricultural lands. In the Grant Park area where cultivated crops are limited, the population appears to be regulated by annual dry conditions and by variation in annual acorn production.

One of the policies of National and California State Parks is to preserve or restore pristine conditions on parklands. Under these policies the presence of pigs, even at low densities, is undesirable. However, under the management programs employed by many of California's regional park districts, including Santa Clara County Parks and Recreation Department, livestock grazing and other land uses have major impacts on vegetation. The presence of exotics, such as wild pigs, may not be in conflict with these regional park policies. The long-term effects of pig rooting on vegetation of grazed rangeland has not yet been determined.

Although seasonal rooting occurred in oak woodland and rangeland of Grant County Park throughout the study, pigs were not considered to be a significant management problem until the summer of 1980, when they entered picnic areas and rooted cultivated lawns. All of the pigs captured near these developed areas were juveniles or lactating sows. Fence construction provided a long-term solution where damage was the most intense. We expect that, in years of high pig recruitment, sows and juveniles will increase activity and cause damage in developed areas adjacent to pig habitat throughout their range.

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COYOTE DIETS ASSOCIATED WITH SEASONAL MULE DEER ACTIVITIES IN CALIFORNIA [1]

JAMES R. SMITH
Pacific Gas and Electric Company
3400 Crow Canyon Road
San Ramon, CA 94583

Food habits of coyotes, *Canis latrans,* were evaluated for three seasons in association with activities of a migratory herd of mule deer, *Odocoileus hemionus.* Sampling periods coincided with deer concentration on the winter range (spring), fawn drop on the summer range (summer), and the sport hunting season (fall). Diets, determined by frequency of occurrence of food items in scats, shifted from predominantly small mammals in the spring to fruit (primarily manzanita berries, *Arctostaphylos* spp.) in the fall. Deer were a minor diet constituent during all three sampling periods and no significant changes were noted among the seasonal sampling periods, or between ranges.

INTRODUCTION

The North Kings deer herd in eastern Fresno County, California, the focus of a multi-agency study from 1971 through 1982, has declined by about 80% since 1955. The decline is attributed to heavy use of the range by deer and livestock, reduction of available habitat by development, extensive fire protection and suppression, long-term dry weather patterns, past hunting practices, and predation (Bertram 1984). Predation is thought to be a major regulating factor on the North Kings deer herd (Chapel and Rempel 1981). High rates of predation by mountain lions, *Felis concolor,* coyotes, and domestic dogs on both adults and fawns, combined with a low deer population, is possibly preventing an increase in the mule deer population (Bertram 1984).

Salwasser (1974) and Rempel (1978) found that fawn remains occurring in coyote scats from the area were high during the fawning period, roughly mid-June through early August. Rempel (1978) also found a high frequency of deer remains in coyote scats during November, when deer remains from the sport hunting season were available for scavenging.

This study provides seasonal information on coyote diets during 1986 in relation to deer concentration on the winter range, fawn drop on the summer range, and the sport hunting season.

STUDY AREA

The study was conducted within the Sierra National Forest on the west slope of the Sierra Nevada in Fresno County, California. The Kings River bisects the herd's range, which encompasses about 2,077 km^2 and varies in elevation from about 300 m to over 3,900 m (Salwasser 1974).

Because of heavy snow at high elevations, deer are on low elevation (300–1,400 m) winter ranges from about November through early May. Major habitat types on the winter range include annual grassland, blue oak woodland, blue oak-digger pine, and mixed chaparral (Mayer and Laudenslayer 1988).

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Spring migration occurs in May and June, with plant phenology being a major factor in determining timing of migration (Bertram 1984). Summer ranges (1,800–3,900 m) are occupied from about June through October. Parturition, fawn rearing, and most hunting occurs on the summer range. Habitats on the summer range are ponderosa pine, Sierran mixed conifer, red fir, and lodgepole pine (Mayer and Laudenslayer 1988).

Fall migration occurs during a six-week period, generally mid-October through November, depending on the weather (Bertram 1984). Some of the deer hunting season overlaps with fall migration.

METHODS

Coyote food habits were determined from scats collected on roads within the North Kings deer herd range from 15 April through 9 May; 6 June through 6 August; and 15 September through 8 October 1986. Sampling periods coincided with deer concentration on the winter range (November through early May), fawn drop on the summer range (June and July), and the sport hunting season (20 September to 5 October). Occupancy of seasonal ranges was determined by monitoring movements of radio-collared deer from an unrelated study of seasonal migration.

Scats were collected on the winter range during each of the three sampling periods, and on the summer range during the summer and fall. Forest roads were selected by stratified random sampling to establish scat collection transects throughout the geographical and elevational range of the summer and winter ranges. Seventy-two percent of the roads were unsurfaced, 18% were gravel surfaced, and 10% were oiled or asphalt surfaced. Sixty-one permanent transects on these roads were selected randomly. At the beginning of the sampling period, two observers walked the 0.8 km transects, once in each direction, and all scats detected were removed. Fourteen days later, the transects were again walked, once in each direction, and all scats observed were collected (Knowlton 1985). Sixty scats were collected during the spring survey, 216 scats during the summer survey, and 199 scats during the fall survey.

Scats were dried in paper bags, numbered, and analyzed (Mark K. Johnson; School of Forestry, Wildlife and Fisheries; Louisiana State University; pers. comm.). Each scat was placed in a dacron bag and rinsed thoroughly under hot running tap water until all evidence of endogenous soluble waste was removed. This is similar to the method described by Johnson and Hansen (1979). Materials recovered from scats were identified by comparison with reference materials from Fresno County. Hair and feather identification followed Moore et al. (1974) and Day (1966), respectively. Data are presented as relative frequency (%) of occurrence of food items in scats (Salwasser 1974, Rempel 1978, Pederson and Tuckfield 1983, Hamlin et al. 1984). Significant differences in coyote diets among sample periods and between deer ranges were determined with Sokal and Rohlf's (1969:607) method for testing the equality of two percentages.

RESULTS AND DISCUSSION

Small mammals and fruit (primarily manzanita berries) occurred most frequently in the diet of coyotes in the North Kings deer herd range (Table 1). The diet shifted markedly from early spring through summer and into fall.

Small mammals occurred most frequently in the spring samples. Of the small mammals, kangaroo rats, *Dipodomys* sp., meadow mice, *Microtus* sp., and ground squirrels, *Spermophilus* sp., occurred most frequently (Table 2). The occurrence of small mammals declined significantly from spring to summer ($P < 0.001$) and from spring to fall ($P < 0.01$). The occurrence of fruit increased significantly ($P < 0.001$) from spring to summer and from summer to fall. This was probably due to the increased availability of manzanita berries as the season progressed. In the summer sample, the winter range exhibited a greater frequency of fruit ($P < 0.01$) and less occurrence of small mammals than the summer range (Table 3). The phenology of manzanita at lower elevations tends to make berries available earlier on the winter range.

TABLE 1. Relative frequency (%) of food items in coyote scats collected on the North Kings deer herd range in 1986.

Food Item	*Spring (n=60)*	*Summer (n=216)*	*Fall (n=199)*
Mule deer	7	3	3
Small mammals	67	30	18
Birds	0	6	2
Reptiles	11	6	2
Insects	8	8	2
Fruits	5	64	82
Other	21	4	1

TABLE 2. Relative frequency (%) of small mammals found in coyote scats collected on the North Kings deer herd range in 1986.

Food Item	*Spring (n=60)*	*Summer (n=216)*	*Fall (n=199)*
Scapanus spp.	3.2	0	0
Lagomorphs	6.3	1.5	4.6
Spermophilus spp.	7.9	8.3	1.8
Eutamias spp.	1.6	0.8	1.0
Sciurus spp.	0	0.4	0
Thomomys spp.	4.8	1.1	1.8
Perognathus spp.	12.7	1.9	0
Dipodomys spp.	19.0	3.4	0
Neotoma spp.	0	0	0.5
Microtus spp.	7.9	6.7	5.6
Other Cricetidae	3.2	1.9	0.5

TABLE 3. Relative frequency (%) of food items in coyote scats collected on the North Kings deer herd winter and summer range in 1986.

	Spring	*Summer*		*Fall*	
Food Item	*Winter Range (n=60)*	*Winter Range (n=78)*	*Summer Range (n=138)*	*Winter Range (n=49)*	*Summer Range (n=150)*
Mule deer	7	2	5	2	5
Small mammals	67	24	41	19	13
Birds	0	3	8	1	5
Reptiles	11	8	0	2	0
Insects	8	7	12	3	0
Fruits	5	66	45	81	83
Other	21	4	4	1	0

There was no significant ($P > 0.1$) difference in frequency of occurrence of deer in scats among any of the sample periods (spring, summer, and fall), or between deer ranges (winter and summer). The occurrence of deer in scats collected on the summer range during the summer sampling period was not significantly ($P > 0.1$) greater than scats collected on the winter range, despite the fact that deer density was higher and fawns more available on the summer range. The frequency of occurrence of deer remains in scats collected from the summer range during fall was not significantly ($P > 0.1$) different from the other sample periods or the winter range.

During 1986, I found that the percent occurrence of deer in scats was low (3–7%) during seasons when previous investigators found high use of deer by coyotes. Salwasser (1974) found that fawns were the dominant (40–70%) coyote food item for a six-week period from mid-June to late July 1973 in the North Kings herd range. Rempel (1978), in a similar study, determined that approximately 19% of the diet of coyotes on the North Kings deer herd range consisted of deer, and this percentage remained fairly constant from mid-January through mid-June 1974. He also found that fawns occurred in high frequencies (20–60%) in scats from mid-June through mid-September 1974. During November 1974, when deer remains from sport hunting season were available, deer appeared to be almost the exclusive component of the coyote's diet (Rempel 1978).

The substantial difference in the occurrence of deer in scats found in the Salwasser (1974) and Rempel (1978) studies compared to this study may have several explanations. The deer population was lower in 1986 (2,500) than it was in 1973 and 1974 (3,400), as was the coyote population (Bertram 1984). Fawn survival was lower in 1973 (47%) than it was in 1974 (67%) or 1986 (69%) (Bertram 1984). Reduced deer availability and fewer coyotes in smaller groups may have resulted in less deer predation by coyotes. The frequency of small mammals and fruit in the coyote diet during 1986 may be a reflection of food availability; however no comparative data are available on abundance and availability of small mammals and fruit.

Interspecific competition among coyotes, bears, *Ursus americanus,* and mountain lions may have changed substantially since 1973. The bear population has increased since 1973 (Bertram 1984), and following the California moratorium on mountain lion sport hunting in 1971, the number of adult lions using the North Kings deer herd range has increased from about 12 in the early to mid-1970s (Ronald C. Bertram, Calif. Dept. Fish and Game, pers. comm.) to 41 in 1987 (Neal, Steger, and Bertram 1987).

The lack of significant differences in frequency of occurrence of deer in scats among any of the sample periods or between deer ranges, and the substantial difference in diet between the Salwasser (1974) and Rempel (1978) studies and my study, suggest that the consumption of deer and other prey by coyotes within the North Kings deer herd range is variable and probably unpredictable.

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AN OUTBREAK OF BLUETONGUE IN CAPTIVE DEER AND ADJACENT LIVESTOCK IN KERN COUNTY, CALIFORNIA [1]

D. A. JESSUP
California Department of Fish and Game
Rancho Cordova, CA 95670

T. M. WORK
Department of Veterinary Medicine
University of California, Davis
Davis, CA 95616

R. BUSHNELL
Veterinary Extension Service
University of California, Davis
Davis, CA 95616

M. SAWYER AND B. I. OSBURN
Department of Veterinary Pathology
University of California, Davis
Davis, CA 95616

A study was undertaken at the Tejon Ranch in Kern County, California, to clarify the epizootiology of orbivirus infections in resident livestock and wild California mule deer, *Odocoileus hemionus californicus.* Adult hereford cattle serologically positive to bluetongue virus (BTV) were housed in close proximity to seronegative goats, sheep, dairy bull calves and California mule deer. All animals were monitored serologically and virologically for BTV and epizootic hemorrhagic disease virus (EHDV) over a 6 month period. *Culicoides variipennis,* the vector of these viruses, were trapped throughout this time period. Free-ranging deer were also surveyed for BTV and EHDV. All previously seronegative animals seroconverted to BTV. BTV serotype 11 was isolated from captive deer, BTV-10 from free-ranging deer, BTV-17 and 11 from livestock and BTV-17, 11 and 13 from *C. variipennis.* It appears that BTV transmission in deer at the Tejon Ranch occurred most often at lower elevations and was dependent on microhabitats favoring *Culicoides* propagation.

INTRODUCTION

Bluetongue disease (BT) and epizootic hemorrhagic disease (EHD) are caused by viruses of the genus *Orbivirus.* There are 5 serotypes (BTV-2, 10, 11, 13, and 17) of bluetongue virus and 2 serotypes (EHDV-1 and 2) of EHD virus present in the United States (Knudson & Shope 1985). At the time the study described below was done, only 4 serotypes (BTV-10, 11, 13, and 17) of BTV were present in California. *Culicoides variipennis* is the only known vector of bluetongue (Foster et al. 1963; Luedke et al. 1967) and EHD (Jones et al. 1977) viruses, and both viruses have caused clinical and reproductive disease in domestic livestock (Luedke et al. 1977) and wildlife (Pirtle and Layton 1961, Stott et al. 1982, Thomas and Trainer 1970). Epizootics of BTV in wild ungulates have occurred in recent years in Wyoming (Thorne et al. 1988) and California (Jessup; pers. observ.).

Investigations into the epizootiology of BTV and EHDV in livestock and wildlife were undertaken on the Tejon Ranch in Kern County, California in the

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spring of 1981. This ranch (Figure 1) which covers 280,000 acres is the largest single private landholding in the state and consists of brush and rangeland divided by two major mountain ranges of hardwood and coniferous vegetation. The bottom land has fruit and nut orchards on its northwest corner. Beef cattle grazing is the predominant livestock activity on the premises, and limited access deer hunting under the private lands wildlife management access program represents a significant source (about $200,000 in 1981) of income. During 1978–80, there were recurrent abortion outbreaks in cattle on the ranch from which BTV-11 and 13 and EHDV-2 were isolated. The source of infection was of major concern, and three hypotheses about the infection source were investigated: (i) Imported cattle could bring with them any of the four BT or two EHD viruses; (ii) Resident cattle could overwinter the virus and possibly act as reservoirs, becoming viremic only during spring/summer biting midge season (Osburn et al. 1981); and (iii) the possibility of biting midge transmission between domestic cattle and California mule deer or vice versa.

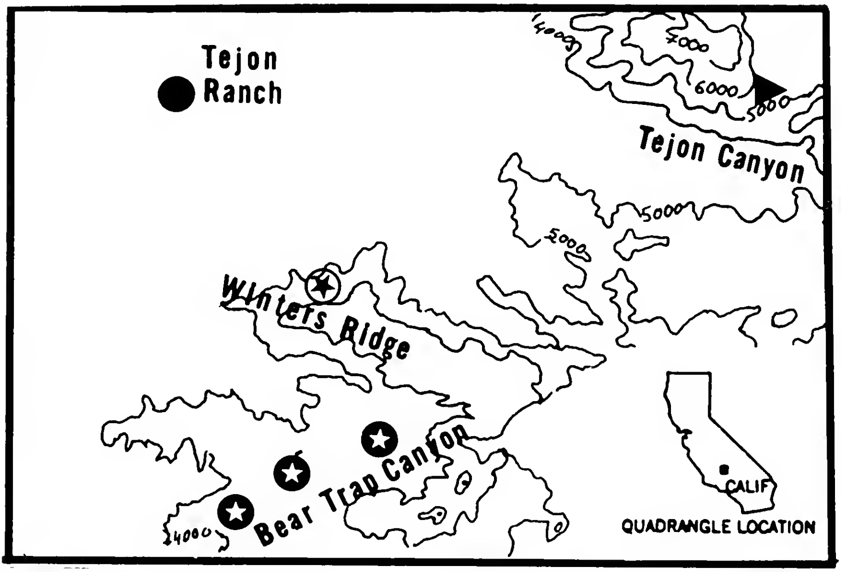

FIGURE 1. Tejon Ranch. Scale: 1 in. = 4 miles. Symbols: ✪ Bear Trap Canyon Insect traps; ▶ Doe with BTV-10; ● Location of animal pens; ⊛ Winters Ridge.

To test these hypotheses, resident BTV seropositive Tejon cattle were housed in close proximity to previously unexposed resident deer, dairy bull calves, sheep and goats. A breeding site for the vector, *Culicoides variipennis,* was provided. Animals were screened for prior exposure to BTV and EHDV serologically and virologically before housing. Subsequent frequent bleeding of all five animal groups and *Culicoides* sampling would determine whether a transmission cycle existed for BTV or EHDV within or between animal groups. Clinical characterization of orbivirus infection in deer and determination of BTV and EHDV prevalence in free-ranging deer on the Tejon ranch were secondary objectives.

MATERIALS AND METHODS

Sample Testing

Serum and blood were stored refrigerated. Heparinized red blood cells were washed twice in physiological saline containing 2mg/ml of penicillin-streptomycin, resuspended to original volume at pH 7.8 and stored refrigerated up to 2 months before laboratory testing. Spleens were washed and two sections (½ × ½ × 1 in.) taken from the central portion. These sections were washed and stored refrigerated in tris buffered saline containing 1mg/ml of gentamycin for up to 3 weeks whereupon they were processed for virus isolation. Red cells or spleen cells were lysed by sonication, diluted 1:10 in saline and 0.1 ml inoculated into each of six embryonating chicken eggs (10–11 days old). Eggs were incubated at 32.5°C for 7 days. Embryo deaths with the characteristic cherry red appearance occurring later than 48 hours postinoculation were considered significant and harvested, ground, sonicated and centrifuged. The supernatant was diluted 1:1000 and 0.1 ml inoculated into another set of six eggs. Fifty percent or more characteristic embryo deaths on the second passage was considered presumptive positive for BTV or EHDV and embryos were harvested, ground, sonicated, centrifuged and adapted to cell culture for serotyping. Sera were tested for antibodies to group antigens of BTV and EHDV using the agar gel immunodiffusion (AGID) test.

Experimental Design

On 10 April 1981, ten California mule deer were captured from Lower Winter's Place on the Tejon Ranch (elevation 3500 feet) by helicopter herding into linear drive nets. All deer were tagged, bled and confirmed serologically and virologically negative for BTV and EHDV. Three deer were released after sampling and marking, and seven remaining deer were transported to holding pens at Tejon Ranch north of the livestock yard (elevation 1000 feet). To replace does that died of trauma, two deer were captured, by chemical immobilization, in May and June near Doe Flat, Lower Winter Ridge road (elevation 3700 feet). They also tested negative for presence of BT or EHD virus and antibodies.

Four fawns were hand captured in June and July of 1981. Three additional fawns were born during June to two captive does. The seven fawns were raised in a weaning shed ⅛ mile northeast of the study pens. Fawns were bottle fed cow colostrum the first day and fawn formula for the first week. Over the next month fawn formula was given in a 1:5 mixture with a commercial sheep formula. This 1:5 mixture was given in decreasing amounts until mid-August depending on age and condition of fawns. Calf manna, omolene, alfalfa hay and pellets, mineral blocks and salt blocks were provided ad lib. On 17 September, three fawns were placed in the experimental pen with the seven adult deer.

Eleven female hereford cattle, five of which were AGID positive to BTV, were used as possible BTV/EHDV reservoirs for the study and located adjacent to and south of the deer pens. Eleven sheep, 14 dairy goats, and 10 bull dairy calves, all serologically and virologically negative for BTV and EHDV, were located approximately 20 yards north of the deer pens. Centrally located between the pens was a shallow 10 × 20 foot stagnant pond high in organic material designed to serve as breeding habitat for *C. variipennis* (Figure 2). Water level in the pond was kept constant throughout the study.

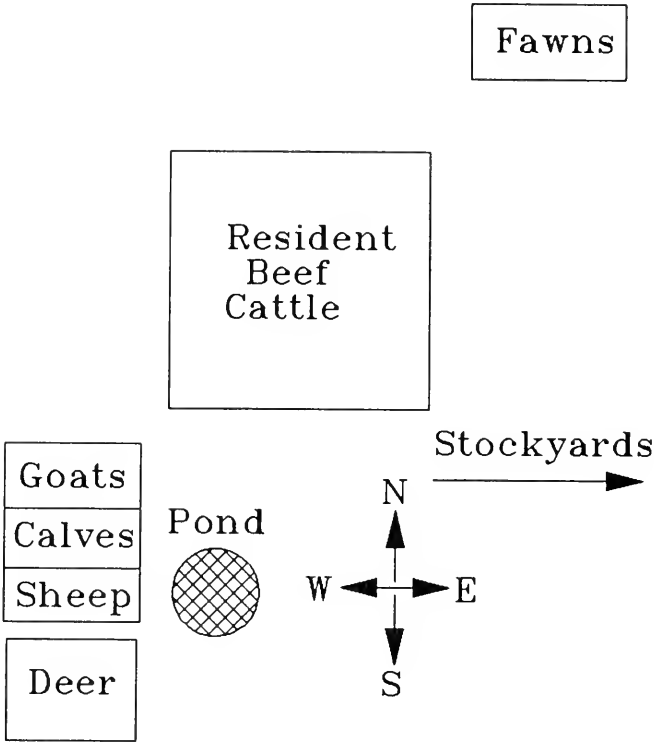

FIGURE 2. Animal pens.
Scale: 1 in. = approx. 125 feet.

All penned animals except deer were bled bi-weekly between April and October. Penned deer were bled tri-weekly. One hundred and eleven sera, 75 washed red blood cell samples, and 69 spleens collected from 128 hunter-killed deer were tested for BT/EHD in an attempt to determine the prevalence of BT and/or EHD in free ranging deer. Blood was also obtained from 11 black tailed jackrabbits and desert cottontails adjacent to the animal pens.

Culicoides variipennis were periodically collected using CDC light traps located ⅛ mile south of the study pens. They were immobilized with CO_2, identified to species, frozen in groups of 25–75 females in a bacteriocide/fungicide solution and processed for BTV and EHDV by inoculating pools of ground insects (20 insects per pool) into vero cells and observing for cytopathic effect at 7 days. All *Culicoides* collections were conducted in areas near the study pens except for one trapping which was done from the head of Bear Trap canyon west of Castaic Lake (Figure 1). Larval *Culicoides* activity was monitored concomitantly.

RESULTS

Five of seven deer present in the pens during August and early September became serologically positive to BTV. All these animals had been serologically negative to BTV/EHDV prior to 31 August. One deer was positive for BTV-11 on 3 August. On 27 August and subsequently, this deer was AGID positive although virus was not detected subsequent to initial isolation. On 27 August, two adult does seroconverted without previous virus isolation and remained seropositive through the end of the study (November 1981) although no virus was ever isolated from them. The remaining two deer were positive for BTV-11 but AGID negative on August 27. One Deer seroconverted on 1 October (five weeks after initial virus isolation) and remained positive until his death on 29 October. Five days after BTV-11 was isolated from the other deer, this animal died unexpectedly. No gross lesions were evident save for random multifocal petechial hemorrhages (<1 mm diameter) distributed on the surface of the heart. A small superficial hemorrhage (1 cm diameter) was located at the apex of the heart. A large hemorrhage (3 cm) approximately 0.7 cm deep was located on the ventral surface of the right ventricle. Microscopic examination of various organs revealed multifocal nonsuppurative vasculitis and thrombosis of small arteries. No other lesions were observed. Bluetongue type 11 was isolated from spleen tissue. Lesions suggestive of BT disease were not noted in other captive deer that died of traumatic injuries during the study.

Fawns did not seroconvert, nor were BTV or EHDV isolated from them during the period from June to September while they were being raised in an open sided covered barn. During the period from 17 September through 29 October when they lived in the pens with adult deer, they did not seroconvert and no BTV or EHDV virus was isolated from them.

Of 75 red blood cell samples from hunter-killed deer, 58 were negative, 17 contaminated, and 1 positive for BTV-10. The BTV-10 positive sample was from an adult doe killed at Cordone Ridge (Figure 1). Of 69 hunter-killed deer spleens, 40 were negative, and 29 were unsuitable for virus isolation. Of 111 hunter-killed deer sera tested for antibodies to BTV, 104 (94%) were negative and 7 (6%) positive. All rabbit samples were negative for BT virus or antibodies except for one jackrabbit which was weakly AGID positive.

Results of penned cows, goats, and sheep have been described elsewhere (Stott et al. 1981). Briefly, 100% of the dairy bulls calves, 82% of the sheep, 79% of the goats and 18% of the adult herefords became viremic with BTV-11 and/or BTV-17 during August and September. All animals seroconverted within 2 weeks of infection; however, presence of AGID antibodies did not always correlate with recovery of virus. Conversely, some animals with detectable viremia were AGID negative to BTV.

Results from biting midge trapping studies were described previously (Loomis et al. 1981). Briefly, adult and larval *Culicoides* populations peaked between late July and October. Bluetongue serotypes 11, 17, and 13 were isolated from biting midges from 1 August through 15 October. Insect sampling ceased after 30 October.

DISCUSSION

The Tejon study provided an excellent opportunity to observe transmission of BTV between domestic livestock and deer and to survey free-ranging deer for exposure to the virus. In the 11 adult resident Tejon hereford cattle, both BTV-17 and 11 were isolated during late summer, yet many were not AGID positive. This may have been the result of relative immunity due to previous exposure to other strains of BTV or EHDV (Campbell 1985) as these cattle were from a seemingly BTV endemic area (as evidenced by the five AGID positive animals). BTV-17 had not been previously documented on Tejon ranch and the source of this serotype is at present unknown. It may have been imported by cattle, migrating deer, windborne *Culicoides* (Sellers et al. 1978) or another as yet undetermined reservoir host.

The ten previously unexposed dairy calves responded quite differently from the herefords in that almost 100% became AGID positive following infection. In these animals, BTV-17 appeared in late July and many virus isolations of BTV-11 and 17 were subsequently made. In two cases, the two BTV serotypes were recovered from the same animal on different dates.

Uninfected sheep and goats responded in a similar manner as uninfected cattle except that presence of AGID antibodies occasionally preceded virus isolation and persisted well into the fall. Bluetongue types 11 and 17 were isolated from most animals and some sheep had oral lesions (hyperemia, erosions and ulcers) during the viremic period suggestive of BT disease (Mahrt et al. 1986).

All deer present in the pens during August seroconverted or had BTV isolated from blood or tissues. Because of the fairly long interval between bleeding of deer (3 weeks) and the apparently short period of viremia (2–3 weeks), virus was not isolated from some animals prior to seroconversion. Only BTV-11 was isolated from deer despite the presence of both BTV-17 and 11 in cattle, sheep, goats and biting midges.

It appears that the unique microenvironment around the deer pens and close contact with infected domestic livestock resulted in infection of all deer by BTV. Two surviving does were AGID positive and virus negative through the winter and into the spring of 1982. By June 1982, one doe had reverted to AGID negative. This suggests that AGID antibody in mule deer and prevalence rates based on these antibodies may not be reliable greater than 8–9 months post-exposure.

Hunter killed deer were sampled from various areas on the ranch with most deer taken from higher ridges on either side of Bear Trap Canyon in the fall. In some of the most intensively hunted areas, AGID positive animals were identified and this antibody is probable evidence of exposure to BTV during the summer *Culicoides* season. The fall exposure rate to BTV in free-ranging deer appeared to be approximately 6% for 1981. Most of the seropositive deer were killed in areas containing potential biting midge breeding habitats. The difference between apparent high exposure rates at the lower elevations compared to low exposure rates at higher elevations again suggests that microenvironment may be a factor determining risk of clinical BT in deer.

At the low exposure rate seen in the fall of 1981, it is possible that the ten deer captured, sampled, and found to be AGID negative in the spring had indeed not been exposed the year before. It is also possible that these deer, like the Tejon herefords, came from a BTV endemic area and therefore had a similar relative immunity with a concomitant undetectable or waned AGID titer. The apparent reversion to seronegative AGID antibody in half of the does sampled through the spring of 1982 suggests that AGID is not a reliable test in deer for BTV exposure beyond 8–9 months. Data from cattle also indicate the lack of sensitivity of the AGID test as a diagnostic tool for BTV in these animals.

Fawns raised in captivity, only 100 feet from hereford cattle and 400 feet from the other animals and *Culicoides* breeding habitat should have been exceedingly sensitive to BTV but no sign of infection was detected at any time. This may have been a result of the fawns being housed in an open sided but covered area into which *Culicoides* would have hesitated to enter. It is also possible that colostral immunity provided protection against infection that was not detectable using the AGID test. It appears that does surviving BTV-11 infection did not serve as a source of virus for susceptible young deer in spite of prolonged intimate contact from mid-September to the end of October.

Gross and microscopic lesions in one deer were consistent with BT disease (Howerth 1988) and viremia with BTV-11 confirmed that diagnosis. As noted, captive deer were under considerable stress prior to that time and suffered traumatic injuries in their pens. Adaptation to an artificial diet and stress of captivity are potentially immunosuppressive possibly leading to more florid manifestations of clinical BT disease.

A doe killed on Cordone ridge (elevation 4000 feet) was viremic (8 November) with BTV-10 but was AGID negative. Bluetongue virus type 10 was not isolated from insects or animals during previous studies in 1978–80. Several factors suggest localized BTV transmission dependent on deer and/or cattle and *Culicoides* interactions: Not only was this doe infected with a unique virus type not found in the livestock yards, but she was apparently early in infection, at a high altitude, in a rather remote section of the ranch and killed at a time period usually considered past prime biting midge season. The lack of AGID antibodies indicates an early stage of the infection again supporting localized vector activity. Deer marked, collared, and sampled on Tejon Ranch were found to migrate as far as 14 air miles making conclusion concerning individual deer home ranges and location during the infectious period difficult when based on spot kills. The presence of a few apparently naturally infected deer, *Culicoides,* and repeated yearly isolations of BTV at Tejon ranch reenforces the likelihood that BTV is endemic in this area, particularly at low elevations and in microenvironments such as warm still muddy shallow sided ponds high in organic matter (O'Rourke et al. 1983), a situation often seen in stock ponds in the Bear Trap drainage.

Culicoides variipennis trapped near experimental pens revealed a definite cycle with virus isolations peaking in mid-August, September, and October. One group of *Culicoides* was trapped in the Bear Trap drainage east of Castaic Lake (elevation 2500 feet). Not only were these insects present at higher altitudes and in areas frequented by both deer and cattle, but BTV-13 was also isolated from them. Bluetongue serotype 13 was not isolated from experimental animals or at other locations during 1981 but had been identified in Tejon cattle during 1978–9. The isolation of three serotypes of bluetongue in these insects confirms *C. variipennis* as a suitable host of BTV in the field.

Definite conclusions as to the source of the virus cannot be made under the present experimental design. As BTV-11 and 17 were isolated from biting midges and various livestock almost simultaneously on 13 August, and because livestock became seropositive to BTV in late July, it would appear that cattle were a source of virus. Deer were the first animals from which BTV-11 was isolated on 3 August, however, these animals were AGID negative throughout spring and summer, making it unlikely that they were harboring a latent infection of BTV-11. The possibility still exists that *Culicoides* feeding activity on deer may have caused a resurgence in a latent and undetectable viremia as has been shown with cattle (Luedke et al. 1977). On the other hand, the virus may have been introduced into the captive animal community from a wild reservoir host or via cattle in transit on the ranch.

In summary mule deer are susceptible to infection with BTV, especially those exposed to *Culicoides* and high densities of infected livestock. Stressed California mule deer may die from BTV infection. Infection appears to occur most frequently in mid to late summer at lower elevations but may also occur at higher elevations as well. Stagnant stock ponds appear to be a significant factor in BTV transmission, and clean stock tanks may reduce breeding and exposure of animals to *Culicoides* and BTV. The AGID test appears unreliable for detection of BTV infection in deer greater than 9 months post-exposure. Separation of fawns from livestock and confinement in an open sided covered building prevented infection in this age group.

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RAINBOW TROUT STRAINS IN CALIFORNIA STATE HATCHERIES [1]

BRUCE G. BARNGROVER
Department of Fish and Game
Mad River Hatchery
1660 Hatchery Road
Arcata, CA 95521

The California Hatchery System currently maintains broodstock for eight strains of rainbow trout. This report describes the history and the current production schedule for each strain and provides information concerning the performance of each in the hatcheries and in the receiving waters.

The broodstock hatcheries of California will produce about 46 million eyed rainbow eggs in 1989, while about 12 million catchable sized fish and almost 4 million fingerlings will be reared in trout production facilities.

INTRODUCTION

The rainbow trout, *Oncorhynchus mykiss*, is native to many waters of California (McAfee 1966). It originally occurred in a large part of the trout streams of the State and in a few lakes. Since this is the fish most commonly raised in the trout hatcheries of California, it has been planted in nearly every lake and stream which is suitable for trout. Therefore, it is by far the most widely distributed trout in California (Anonymous 1957).

Trout culturists have developed domesticated trout strains well adapted to hatchery life. These fish are easier and less expensive to raise than wild strains and are typically more vulnerable to angling. They perform well in most phases of trout stocking, especially in put-and-take (catchable) programs (Borgeson 1966).

Several strains of rainbow trout have been domesticated or developed through generations at California hatcheries. Currently, eight strains are being propagated, with the majority of the fish resulting from eggs taken at Hot Creek, Mt. Shasta, and Mt. Whitney hatcheries.

The hatchery system of the California Department of Fish and Game (CDFG) will produce 15,542,000 rainbow trout in 1989. These trout, weighing almost 4 million pounds, will be produced and distributed by 15 hatcheries (Figure 1, Table 1) throughout the State for the express purpose of providing quality fishing opportunities for the anglers of California.

Rainbow trout are produced and stocked in three size categories. Catchables (6/lb. or larger) are stocked in heavily fished roadside streams and lakes. Subcatchables (6.1/lb.–16/lb.) are stocked in waters with a potential for growth, and fingerlings (16.1/lb. or smaller) are utilized primarily to stock barren waters, waters that have inadequate recruitment, and lakes where fingerlings will provide an adequate fishery.

Catchable-sized fish will comprise 75% of the numbers of rainbow trout produced and almost all of the weight.

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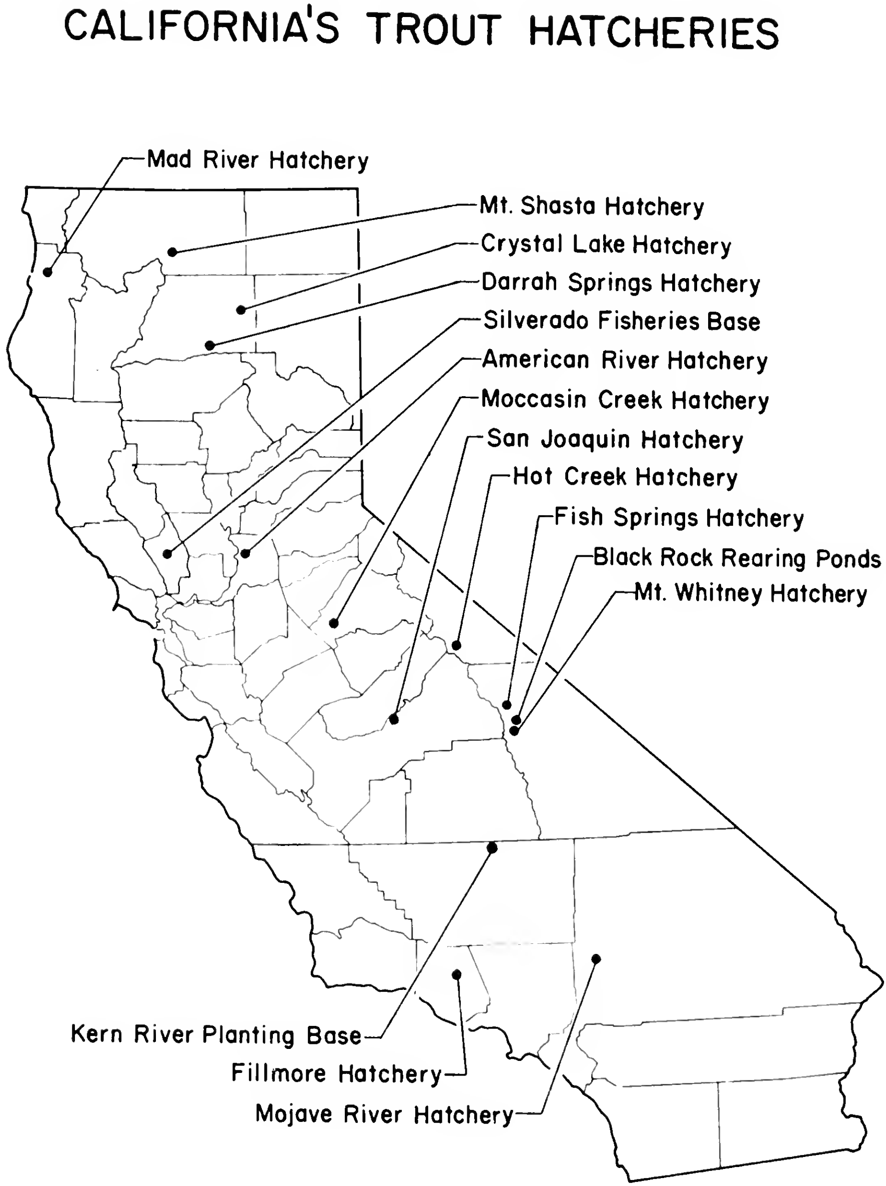

FIGURE 1. California's trout hatcheries.

TABLE 1. Rainbow Trout Strains Cultured at California State Trout Hatcheries.

Hatchery	*RTW*	*RTH*	*RTC*	*RTS*	*ELT*	*RTP*	*RTS x RTKJ*	*RTKJ*
American River	X	X		X	X		X	
Crystal Lake		X	X	X	X	X		
Darrah Springs	X		X	X	X		X	X
Fillmore	X	X	X					
Fish Springs	X	X	X					
Hot Creek	X	X	X					X
Mad River				X				
Moccasin Creek	X	X	X					
Mojave River	X	X	X					
Mt. Shasta				X	X		X	
Mt. Whitney/Black Rock	X							
San Joaquin	X	X	X					

BACKGROUND

The strains of rainbow trout currently being propagated in California State hatcheries include: Mt. Whitney (RTW), Hot Creek (RTH), Mt. Shasta (RTS), Coleman (RTC), Pit River (RTP), Junction Kamloops (RTKJ), Eagle Lake (ELT), and a hybrid RTSxRTKJ (RTS eggs fertilized with sperm from RTKJ males). A few other strains are being cultured on an experimental basis with the possibility of utilizing one or more of them to improve or replace one or more existing broodstock strains.

Three major broodstock hatcheries plus Crystal Lake Hatchery and egg taking stations at Eagle Lake and Junction Reservoir will produce a total of 46 million rainbow trout eggs in 1989.

Since 1976, three of the major California rainbow trout broodstocks (RTH, RTW, and RTS) have undergone an intensive two-stage selection process involving family identification by multiple fin clips, single pair mating and performance testing for egg size, number of eggs per female, hatchability, and size at yearling (Gall 1977). This program was a refinement of a simpler one (Gall 1972) developed in the early 1970's by Dr. Graham Gall, a geneticist with the University of California at Davis.

The objective of the program is to develop quality brood fish which will improve, through genetic means, the economics of egg production as well as the production of catchable size trout by achieving the desired size in the least possible time (Table 2).

TABLE 2. Mean Seasonal Temperatures (° C) by Quarter and Time Required to Rear Rainbow Trout to Catchable Size in California State Fish Hatcheries.

Hatchery	*Jan–Mar*	*Apr–June*	*July–Sept*	*Oct–Dec*	*Months required*
Crystal Lake	8.9	9.4	10.0	8.9	12–14
Mad River	10.0–11.1	10.0–15.6	15.6–18.3	10.0–18.3	11
Darrah Springs	12.8	13.3–13.9	14.4–15.0	13.9–14.4	9–10
Mt. Shasta	5.0	6.1	7.8	6.7	17
American River	7.8	10.0–10.6	15.6	10.0–15.6	10
Moccasin Creek	7.8–8.9	7.2–8.3	10.0–11.1	11.7–12.8	10–12
San Joaquin	8.3	10.0	12.8	12.2	10+
Black Rock	8.9	13.3	13.3	8.9–13.3	10+
Fillmore	14.4	14.4	15.6	14.4	9
Fish Springs	14.4	15.0	15.6	14.4	9
Hot Creek	15.0	15.0	15.0	15.0	10+
Mojave River	15.6	15.6	15.6	15.6	10

Included in this program is a mechanism to allow the hatchery manager to alter the spawning time of the broodstock either earlier or later or to broaden or narrow the peak time of spawning.

Selection for season of spawning is necessary to provide egg production over a period which satisfies the seasonal requirements for fish. However, selection of breeding fish which spawn at a desired time will determine the fish available for consideration in selection for other performance characters. The need to control inbreeding by spawning fish from a minimum of parental families also imposes a restriction of extent of selection for spawning time.

The five strains which are cultured without the structured selection process do in fact undergo a less regimented selection, mostly at the discretion of the hatchery manager or the culturist actually doing the spawning. In some cases spawners are chosen for size or conformation, while some broodstock are spawned at random to ensure the continuance of all available genes. Time of spawning can be influenced by keeping eggs for future broodstock from lots of eggs spawned early, late, or in the middle of the current spawning season of any stock.

STRAINS

The Mount Whitney Strain (RTW)

Colorful indeed is the history of the Mt. Whitney strain of rainbow trout. Eggs collected at Rae Lakes in the heart of the southern Sierra as early as 1917 produced the first fish hatched at Mt. Whitney Hatchery (Leitritz 1970). Eggs from several other interesting sources such as the Eel River, the Klamath River, Lake Tahoe, Big Bear Lake, and June Lake (Busack and Gall 1980), were among the beginnings of the current Mt. Whitney strain, which includes steelhead rainbow trout, *Oncorhynchus mykiss*, and cutthroat trout, *O. clarki henshawi*, in its ancestry.

Located near Independence on the alluvial slope of the eastern Sierra, the impressive stone edifice of Mt. Whitney Hatchery has been home to the Mt. Whitney rainbow since 1917. Because Mt. Whitney is a coldwater hatchery, (Leitritz 1970), the selected broodstock are reared at Black Rock Rearing Ponds, which have a more temperate water supply to promote growth. The broodfish are returned to Mt. Whitney's cooler water for the last few months before spawning to allow better egg development than is possible in the warmer water at Black Rock.

Mt. Whitney was discovered to be infected with whirling disease, *Myxosoma cerebralis*, in 1984 and since then a duplicate set of broodstock has been maintained at San Joaquin Hatchery as a backup. Eyed eggs are available from Mt. Whitney (eggs do not carry whirling disease after they have been disinfected with an iodine based disinfectant) from early March through May. Mt. Whitney will produce 12 million eyed eggs in 1989 (Figure 2).

Catchable-sized Mt. Whitney rainbows are reared and distributed by American River, Fillmore, Fish Springs, Mt. Whitney, Black Rock, Mojave River, Moccasin Creek, Darrah Springs, Hot Creek, and San Joaquin hatcheries (Table 1).

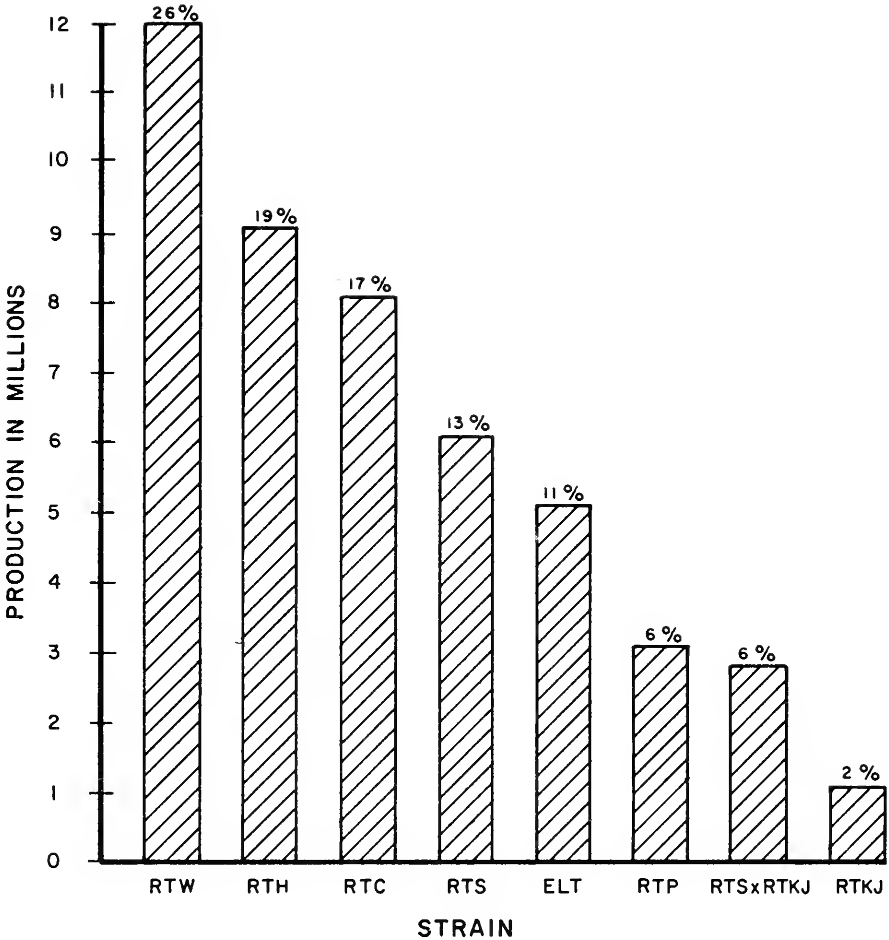

FIGURE 2. Projected 1989 production in millions of eyed eggs for the eight strains of rainbow trout propagated for distribution by California hatcheries.

The Mt. Whitney strain performs well and grows quickly in the hatcheries but is more likely to suffer fin erosion than some strains. It is somewhat resistant to disease but, as will all trout, can become involved with disease when crowded. Body conformation of the RTW is that of a typical rainbow trout, ideal for setting a standard for the species. Very few of the RTW suffer abnormalities. They are generally heavily spotted with small spots but are not as dark as the Hot Creek rainbows. As with other domesticated strains of long standing, the RTW are easily caught and perform well in put and take fisheries. The RTW have shown a tendency to emigrate downstream during high water, which may limit their usefulness in large impoundments (Rawstron 1973). However, if an efficient downstream fishery can be maintained, that tendency may not be entirely detrimental.

The Hot Creek Strain (RTH)

Hot Creek Hatchery in Mono County near Mammoth Lakes is home to the Hot Creek rainbows. Clear spring water of constant 11.7–13.3°C temperature is suitable for broodstock and egg development and for trout production at Hot Creek. They spawn in the late summer and the eyed eggs are available from late July to mid-September (Figure 3). Hot Creek Hatchery will take 5,000,000 eggs in 1989.

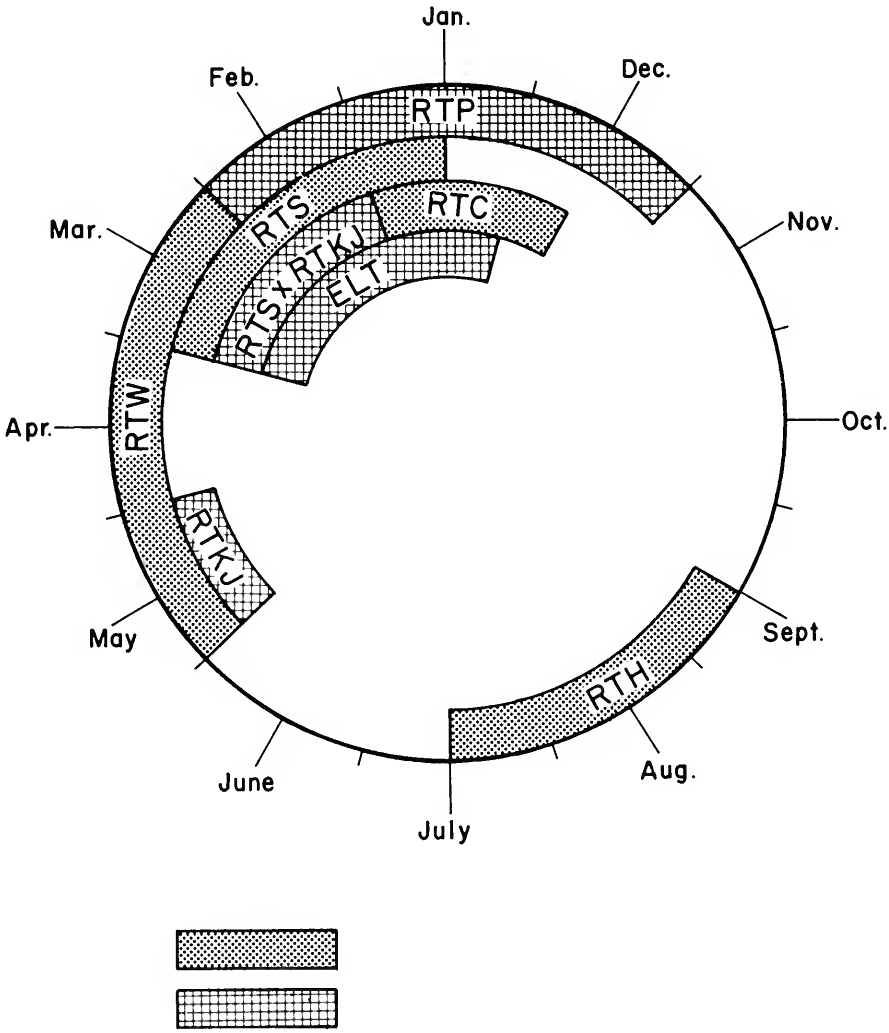

FIGURE 3. Periods of eyed egg availability of the broodstock strains of rainbow trout in California Department of Fish and Game hatcheries. Cross hatched areas represent special purpose strains; dotted areas represent major broodstocks.

The Hot Creek strain, in common with virtually all rainbow strains, originated in the McCloud River in California. In 1933 a shipment of eggs was obtained from Springville, Utah, which, through selective breeding there and at Neosho, Missouri by the U.S. Fish Commission, had been developed into a fall-spawning strain (Leitritz 1959).

In 1953, females were out-bred to Whitney males to increase genetic variability, and, in 1965, the RTH strain was crossed with a strain of rainbows originally from Virginia in an effort to correct problems arising from inbreeding. The Virginia strain had a similar spawning time. The problem persisted, particularly an undershot jaw condition commonly called "Ubangi."

The characteristic Ubangi jaw of the RTH strain has been reduced to a low incidence through selection but other problems have developed. A tendency for the RTH fish to suffer from bleeding gills has departmental pathologists and the Broodstock Committee attempting to rejuvenate or replace the strain. Some fish of "Erwin" strain rainbows, which are from the original Hot Creek strain, which have been cultured at Ennis, Montana, are being reared at Hot Creek for possible infusion into the RTH strain.

A duplicate set of RTH broodstock is kept at Crystal Lake Hatchery as a backup for the Hot Creek broodstock and is used for some production. Crystal Lake Hatchery will produce 4 million eyed RTH eggs in 1989 that will be reared by Fish Springs, San Joaquin, and Moccasin Creek hatcheries (Table 1).

The Hot Creek strain is used for production at Hot Creek, Fish Springs, Mojave River, Crystal Lake, San Joaquin, American River, Fillmore, and Moccasin Creek hatcheries (Table 1).

The Hot Creek rainbow grows quickly and is less prone to fin erosion than some strains. It is susceptible to diseases associated with crowding and the fish suffer from gill bleeding when being loaded for transport or otherwise stressed. They tend to be darker in hue and deeper bodied than some strains of rainbow trout.

Hot Creek rainbows perform well in put-and-take waters. They are easily caught by anglers and are an attractive representative of the species. The RTH grows rapidly to catchable size in hatcheries, reaching ⅓ pound in less than a year in most production facilities.

The Coleman Strain (RTC)

The Department acquired the Coleman strain in 1968 from the Coleman National Hatchery in Anderson, California; Mt. Shasta Hatchery initially cultured this newly acquired strain. This strain began at Coleman in 1949 from a shipment of Kamloops trout eggs from Pennask Lake, British Columbia. Over the years at Coleman it was mixed with steelhead and resident rainbow trout from Battle Creek (Busack and Gall 1980). The Coleman strain was moved from Mt. Shasta Hatchery to Hot Creek Hatchery in 1969 and is now maintained at Hot Creek. Hot Creek Hatchery will produce 8 million eyed RTC eggs in 1988–89 from mid-December through January (Figure 2). Coleman strain is reared at Hot Creek, Crystal Lake, Darrah Springs, Moccasin Creek, San Joaquin, Fillmore, Fish Springs, and Mojave River hatcheries (Table 1).

The RTC strain grows well in hatcheries, reaching catchable size in 9–12 months depending on water temperatures. They are more resistant to disease than some rainbow strains and are considered a good strain to raise by most hatchery managers.

The RTC have been found to orient themselves to the deeper portion of large reservoirs and, as a result, contribute to the fishery over a longer period of time (while growing larger) than more domesticated strains which are more available to efficient shore anglers and thus contribute to the catch more during the first few months after stocking (Rawstron 1977). In Topaz Lake, Coleman strain rainbows were found to contribute to the catch over a longer period of time because of slower catch rates (John M. Deinstadt, Calif. Dept. of Fish and Game, pers. comm.).

The RTC apparently have a tendency to emigrate from a reservoir. They have been caught 5 miles upstream in the Tuolumne River after being released in Don Pedro Reservoir (Laird Marshall, Sr., Calif. Dept. of Fish and Game, pers. comm.). Their predilection for open water areas does decrease their availability to shore anglers. These are relatively minor problems, however; they are superior to more domestic strains in a majority of situations (Cordone and Nicola 1970).

The Mount Shasta Strain (RTS)

California's oldest operating fish hatchery is the home and namesake for the Mt. Shasta strain of rainbows. The RTS have been propagated at Mt. Shasta Hatchery since the early 1950's. The ancestors of the Mt. Shasta rainbows include the Hot Creek strain and a strain of domestic rainbows grown at a private farm in Idaho (Busack and Gall 1980). The RTS strain is currently maintained through the two-stage selection process at Mt. Shasta Hatchery in conjunction with Darrah Springs Hatchery.

The fish are spawned at Mt. Shasta Hatchery and the eggs from selected matings for future broodstock are sent to Darrah Springs Hatchery where they are hatched and the fish reared in the warmer water available there which is conducive to rapid growth. A few months before 2-year-old fish will spawn, they are returned to Mt. Shasta where the colder water promotes proper egg development.

The Mt. Shasta Hatchery will produce 6 million eyed eggs in 1989 and catchable RTS will be reared at Mt. Shasta, Crystal Lake, Darrah Springs, American River, and Mad River hatcheries (Table 1).

Mt. Shasta rainbows grow well in hatcheries, reaching catchable size in 9–12 months depending on water temperatures, and they perform well in put-and-take fisheries. The RTS display a tendency to move toward the outlet or dam area when planted in Shasta Lake and contribute more to the overall fishery if they can be planted in the remote arms of the lake. RTS planted in Don Pedro and McClure Reservoirs are caught near release sites. The body conformation of the RTS is more slender and racier looking than the RTH or TRW.

The Eagle Lake Strain (ELT-W) (ELT-D)

The Eagle Lake trout strain is actually a subspecies of rainbow trout, *Oncorhynchus mykiss aquilarum* (Busack and Gall 1980), that evolved with the ability to survive and grow in the alkaline waters of Eagle Lake in Lassen County.

Because natural spawning of Eagle Lake trout has not been successful in recent years due to the intermittent nature of the tributary stream, this strain is being perpetuated by trapping and spawning fish. Mature spawners are trapped in the springtime at Pine Creek, the only major tributary to Eagle Lake, and a portion of the eggs are hatched and reared at Crystal Lake Hatchery. These fish are marked and released into the Pine Creek estuary of Eagle Lake in the fall with the designation ELT-W (Wild). These marked fish will be the ELT-W spawners when they mature and migrate back to Pine Creek. The remainder of eggs from the Pine Creek spawning go to Darrah Springs Hatchery where they are hatched and reared until near maturity. These fish are then transferred to Mt. Shasta Hatchery where they are spawned. The resultant progeny are designated ELT-D (Domestic). Each generation of ELT-D eggs are hatched and reared at Mt. Shasta, Darrah Springs, and American River hatcheries for stocking as fingerlings, subcatchables, and catchables in selected waters in DFG Regions 1, 2 and 3. ELT-D reared at Darrah Springs are planted as catchables in the spring into the marina at the south end of Eagle Lake to provide a trophy fishery. Eyed Eagle Lake trout eggs are available mid-December to mid-March (Figure 3).

Eagle Lake trout are noted for their tolerance of alkaline waters and for their spots, which are larger than those of other strains.

Eagle Lake trout contribute to the catch over a longer period of time than more domesticated strains in Shasta Lake (Don W. Weidlein, Calif. Dept. of Fish and Game, pers. comm.), Crowley Lake (John M. Deinstadt, Calif. Dept. of Fish and Game, pers. comm.) and Jackson Meadows Reservoir (Hiscox, Calif. Dept. of Fish and Game, pers. comm.). The ELT also out-performed Coleman strain in number and weight returns in a study conducted at Lake Berryessa (Rawstron 1977).

The Pit River Strain (RTP)

The Pit River strain of rainbows is maintained at Crystal Lake Hatchery. It emanated from native Pit River fish captured from Sucker Springs between 1968 and 1970.

The RTP has not been domesticated as long as the RTH, RTW, and RTS and has not been subjected to a structured selective breeding process so the fish grow more slowly in hatcheries and contribute to the catch over a longer period of time in lakes and reservoirs, due, in part, to a tendency to avoid anglers' hooks (Maurice L. McCormack, Calif. Dept. of Fish and Game, pers. comm.). In addition, some fisheries managers feel that the RTP display a propensity to ascend available tributaries rather than remain in a lake or reservoir where planted. (Orville Simmons, Calif. Dept. of Fish and Game, pers. comm.).

Crystal Lake Hatchery will produce about 3 million eyed RTP eggs December through February, and most of the fish will be reared there for release in Shasta Lake, Baum Lake, and other catchable waters in Region 1 (Laird E. Marshall, Jr., Calif. Dept. of Fish and Game, pers. comm.).

The Pit River strain is noted for resistance to the parasite *Ceratomyxa shasta*. In 1989, some of the RTP will be tested at American River Hatchery in Region 2 to see if they also may be resistant to Proliferative Kidney Disease (PKD).

Hybrid Rainbow Strain (RTS x RTKJ)

A hybrid strain of rainbow trout is produced at Mt. Shasta Hatchery by fertilizing eggs from Mt. Shasta strain females with sperm from Junction Kamloops males. The RTKJ males are reared at Darrah Springs Hatchery from eggs sent from Hot Creek Hatchery. Mt. Shasta Hatchery will produce 2,750,000 eyed hybrid eggs February through March in 1989 (Figure 2).

Most of the RTS x RTKJ will be reared to fingerling size at Mt. Shasta Hatchery for air planting in mountain lakes. Darrah Springs Hatchery and American River Hatchery rear RTS x RTKJ to catchable size before planting by truck in selected waters (Table 1).

The RTS x RTKJ grow more slowly in the hatcheries than domestic strains and this trait is sometimes beneficial by having fish reach catchable size during a certain period of the year, when other available strains may reach that size too soon. Trout that become larger than desired for a particular program are more expensive to maintain and transport and may present a potential disease problem because of pond overloading. Also, it is not efficient or effective husbandry to attempt to retard growth by withholding feed or crowding the fish in the ponds.

Some regional biologists prefer the hybrids for mountain lakes, attributing hybrid vigor, longevity, and wild characteristics to the RTS x RTKJ (Tony Nevison, Calif. Dept. Fish and Game, pers. comm.). A tagging study in Jackson Meadows Reservoir found that RTS x RTKJ catchable performed midway between RTS and ELT in yearly returns but, over the 6-year study, yielded a comparable total (John Hiscox, Calif. Dept. of Fish and Game, pers. comm.).

The RTS x RTKJ perform about the same as the RTS in the hatchery rearing process and, while growing a little slower, fill a niche in the hatchery production schedule (Phil Flint, Calif. Dept. of Fish and Game, pers. comm.).

If proposed studies demonstrate that the hybrid RTS x RTKJ do not markedly outperform the RTS after planting, the production of the hybrids may be curtailed because of the inconvenience and expense of maintaining the duplicate RTKJ broodstock.

The Junction Kamloops Strain (RTKJ)

The Junction Kamloops strain is maintained in Junction Reservoir near Bridgeport, Mono County by the personnel from Hot Creek Hatchery. This broodstock was established in Junction Reservoir from Kamloops trout eggs obtained from the Oregon Department of Fish and Wildlife's egg taking stations at Diamond Lake, Douglas County, Oregon.

RTKJ broodstock are trapped or seined from Junction Reservoir in late spring and about 1 million eyed eggs are produced in May (Figure 2).

Each year some of the eggs taken at Junction Reservoir are sent to Darrah Springs Hatchery to be reared and sent to Mt. Shasta Hatchery for spawning. These fish serve as a reserve for the RTKJ broodstock in case of a disastrous winter kill at Junction Reservoir and as a source of males to cross with RTS females to produce the RTS x RTKJ strain.

Hot Creek Hatchery cultures most of the RTKJ and each year RTKJ subcatchables are planted in Junction Reservoir to perpetuate the broodstock, which does not spawn successfully in the reservoir or the intermittent stream which feeds it.

The RTKJ are utilized mainly for air planting as fingerlings in back country lakes and in certain selected mountain lakes which are accessible by truck.

Moccasin Creek hatchery will receive RTKJ eggs in 1989 to rear to fingerling size for planting in high mountain lakes on the west side of the Sierra. San

Joaquin Hatchery may participate in this program when sufficient eggs are available.

The RTKJ is basically a wild strain which is spawned and cultured in a hatchery, but the broodstock lives and grows to maturity in the wild. RTKJ grow more slowly than more domesticated strains in a hatchery situation but may live longer and survive better when planted in back-country lakes as fingerlings.

In a study comparing airplane planted fingerlings of the RTKJ and RTW strains in six high mountain lakes, RTKJ were found to survive at more than twice the rate of the Whitney strain (Partridge 1978). The greatest difference between the strains was in lakes which contained brook trout, *Salvelinus fontinalis.* The percent survival of the Junction Kamloops in these lakes was similar to their survival in lakes which contained only rainbow trout, while the survival of the Whitney strain dropped sharply when brook trout were present.

DISCUSSION

The California State Hatchery system maintains eight different strains of rainbow trout broodstock to maximize the utilization of the rearing capacity of the CDFG Hatcheries, by having eyed eggs available at different times of the year for hatchery managers to start crops of fish on a rotational basis, and by managing for maximum growth (Figure 3). However, three of the strains constitute the bulk of production spawn during the period of mid-December through May, with only the RTH strain providing a fall source of eggs (from mid-July through mid-September).

There are some gaps in the program which may necessitate managing for less than maximum growth in some situations to prevent fish from becoming too large before the scheduled stocking date. If the fish do grow much larger than planned, they may become crowded to the point of a possible health problem and they will certainly be more expensive to transport.

Although the individual broodstock strains have been cultured and maintained for years (60 years in the case of the RTW), the system as a whole is not static but changes over time. The changes can be due either to biological factors or are brought about consciously by hatchery managers to accommodate perceived needs. Hatchery management and fisheries managers are concerned with the quality of the fish released in California lakes and streams, and changes or additions to the broodstocks are contemplated or effected almost constantly in attempts to alter time of spawning, survivability, catchability, or other measures of performance. Over time, almost all broodstocks have been altered, intentionally or not, by hybridization with other species, subspecies, or strains such as Lahontan cutthroat trout, steelhead rainbow trout, or the Virginia strain of rainbow trout (RTV).

Rainbow trout allotments to the production facilities are sometimes manipulated in attempts to provide a particular size of fish or strain of fish with certain characteristics for fisheries management programs (e.g. long-lived, resistant to disease or angling pressure, late maturating). Fisheries biologists may be more concerned with after-release performance characteristics of certain strains of rainbow trout than hatchery managers, who may place more value on the performance of a particular strain in the hatchery environment. Some hatchery managers may feel that the differences in performance of the different strains after release in lakes or streams have been exaggerated.

The Hatchery Operations Committee, consisting of the supervisors of regional fish hatcheries, the Fish Hatchery Manager II in Region 3, and the Hatchery coordinator in the Inland Fisheries Division, formulate plans for the State's rainbow trout program with input from the Broodstock Committee, the fisheries management supervisors, and Graham Gall.

Some items the Hatchery Operations Committee is addressing are:

(i) The problem of gill bleeding in the RTH.
(ii) Possible replacements for RTH broodstock.
(iii) The lack of eyed eggs available in early summer and late fall.
(iv) The need for maintaining duplicate sets of broodstock.
(v) The planting of catchable fish by pounds rather than numbers.
(vi) The move toward larger size catchables (2/lb rather than 4 to 6/lb).
(vii) The pressure from private growers to sell rainbow trout to the State.

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EVALUATION OF WILDLIFE-HABITAT RELATIONSHIPS DATA BASE FOR PREDICTING BIRD COMMUNITY COMPOSITION IN CENTRAL CALIFORNIA CHAPARRAL AND BLUE OAK WOODLANDS [1]

MICHAEL L. AVERY [2] and CHARLES VAN RIPER III [3]

Department of Wildlife and Fisheries Biology, and
Cooperative Parks Studies Unit,
University of California
Davis, CA 95616

The California Wildlife-Habitat Relationships (WHR) data base assists resource managers in evaluating effects of habitat manipulations on wildlife populations. However, the reliability of the WHR data base has been subjected to few field tests. We evaluated the accuracy of predictions made by WHR utilizing data from bird community surveys at Pinnacles National Monument during the winter and spring of 1984 and 1985. Using variable circular plots to compile species lists from the field, data were compared with species lists generated by WHR for vegetation habitat types in chamise-redshank chaparral, mixed chaparral, and valley-foothill hardwoods.

Two types of discrepancies were recognized: (i) "errors of commission" (species listed by WHR but not recorded in the field), and (ii) "errors of omission" (species recorded in the field but not listed by WHR). Valley-foothill hardwood had few errors of commission, but errors of omission averaged 22% in the winter and 19% in the spring. Errors of commission in the chaparral types ranged from 12% to 39%. In chamise chaparral, errors of omission ranged from 12% in the winter to 46% in the spring. The mixed chaparral error rates were 24% and 41%, respectively.

Additional effort should be directed toward field testing the predictive accuracy of the WHR data base. This is essential if WHR is to be used as an effective wildlife management tool.

INTRODUCTION

The California Wildlife-Habitat Relationships (WHR) Program was developed to create a standardized data base for wildlife species and their habitats (Grenfell et al. 1982). This WHR program is part of a multiagency national wildlife and fish habitat relationships program (Nelson and Salwasser 1982). The WHR data base is an information system that describes distribution, status, natural history, and habitat requirements of each terrestrial wildlife species. It is hoped that this information system will provide resource decision-makers and managers with current information about wildlife distributional patterns and capabilities of various habitats to support wildlife.

The usefulness of the WHR system is ultimately determined by how accurately it reflects events in the real world. The best way to evaluate the predictive accuracy of the California WHR system is by comparing its predictions to data collected in the field. In December 1983, we began a resource inventory at Pinnacles National Monument, San Benito County,

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[2] Present address: USDA/APHIS, Denver Wildlife Research Center, 2820 E. University Ave., Gainesville, FL 32601.

[3] Present address: CPSU/NAU, P.O. Box 5614, Northern Arizona University, Flagstaff, AZ 86011. Address all correspondence to this author.

California. As part of that project we surveyed the avifauna throughout the Monument (Avery and van Riper 1986), and in this paper compare our findings to the bird communities predicted by the WHR system for chamise chaparral, mixed chaparral, and blue oak woodland.

METHODS

Pinnacles National Monument is located in the southern Gabilan Mountains, about 150 miles (240 km) south of San Francisco and 40 miles (64 km) east of Monterey, California. Over 80% of the 16,000 acre (6400 ha) park is covered by chaparral vegetation, with the remainder a mixture of foothill and riparian woodlands and bare rock (Webb 1969). There is a Mediterranean-type climate, with cool, wet winters and hot, dry summers. Precipitation averages 42 cm annually, with about 80% occurring during the December-March period.

Candidate sites at which to conduct bird surveys were selected using a 1:12,000 scale vegetation map prepared from aerial photographs taken in August 1983 (Figure 1). Criteria for candidate site selection included size of the stand (at least 5 ha), distance from the center to the edge of another habitat type (at least 75 m), and accessibility (relatively close to a marked trail). We purposely restricted our sites to those with no recent fire history in order to reduce variability due to plant age. Thus, all sites have been unburned for at least 30 yr. None of the sites has been grazed.

After inspecting candidate sites, we selected 33 permanent study plots among three habitat types:

1. Chamise chaparral (12 sites) is restricted to the dry south- and west-facing slopes throughout the Monument. Chamise (*Adenostema fasciculata*) accounts for most of the shrub cover, with buckbrush (*Ceanothus cuneatus*) and California buckwheat (*Eriogonum fasciculatum*) the only other shrubs of importance. Most sites had a sparse ground cover of annual grasses.
2. Mixed chaparral (7 sites), the most common vegetation type in the Monument, is dominated by chamise and buckbrush, but may include substantial components of manzanita (*Arctostaphylos glauca* and *A. pungens*), flowering ash (*Fraxinus dipetala*), scrub oak (*Quercus dumosa*), California buckwheat, and hollyleaf cherry (*Prunus ilicifolia*). This plant community occurs on north-facing slopes, and the ground cover includes annual grasses or ferns and various other shade-tolerant native species.
3. Blue oak (*Quercus douglasii*) woodland (14 sites) occurs on hillsides throughout the Monument and is variable in stand age and structure. The oaks may be interspersed with digger pine (*Pinus sabiana*) or California juniper (*Juniperus californica*). The understory component may include chamise, redberry (*Rhamnus crocea*), mountain mahogany (*Cercocarpus betuloides*), flowering ash, or buckbrush. The herbaceous ground cover is dominated by introduced annual grasses but also includes a rich mixture of native forbs.

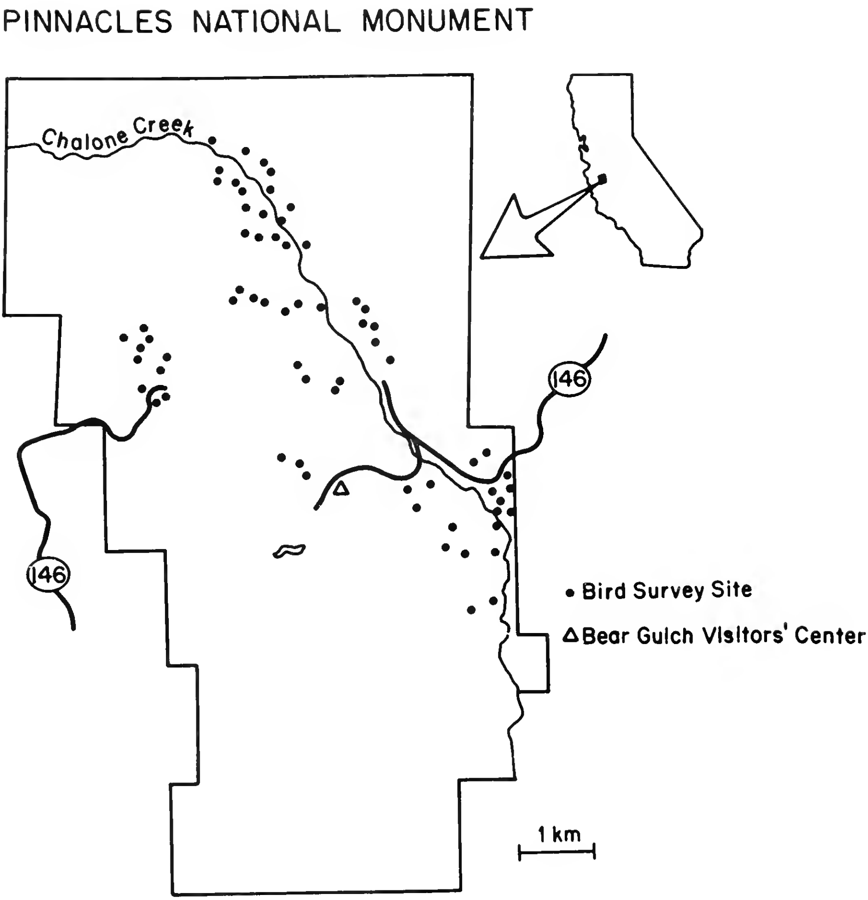

FIGURE 1. Map of Pinnacles National Monument, California, depicting locations of all permanently marked bird survey sites where censuses were performed.

Shrub and ground cover were measured at each chaparral site along a randomly placed 30-m transect. In addition, at 2-m intervals along the transect, a ruler was dropped vertically through the vegetation and the following data recorded: canopy height, points of contact of the ruler with live and dead vegetation, and litter depth.

In the oak woodland, sampling of vegetation cover was done by determining points of contact at 2-m intervals along 25-m transects extending from the center of each site in each of the four cardinal compass directions. Estimates of tree, shrub, and herbaceous cover were determined by averaging the percentages of contacts for the four transects.

We visited the 33 study sites three times during each of the following periods: 21 December 1983—22 February 1984, 2 April—5 June 1984, 23 November 1984—21 February 1985, and 2 April—27 June 1985. Bird counts were made using the variable circular plot technique (Reynolds et al. 1980). Field work was scheduled so that no site was visited more than once every 2 weeks. Upon arriving at a site, 1 minute was allowed for the effects of the investigator's activity to abate. Then for the next 5 minutes, all birds seen or heard and the estimated distance from the observer were recorded. Counts started within 30 minutes of sunrise and were completed for the day within 3 hours. To minimize observer variability, one person (MLA) performed all bird counts. Common names of all birds mentioned in the paper, along with four-letter acronyms and scientific names, are included in Appendix I.

In addition to an overall species list for each habitat type, we compiled a list of the most frequently detected species. Both lists were compared to the WHR printouts to evaluate the predictive success of the WHR models in both winter and spring.

Seven lists of species were obtained from the WHR system for San Benito County: chamise-red shank chaparral, age class 4 (senescent), canopy cover M (moderate) and D (dense); mixed chaparral, age class 4, canopy cover D; valley-foothill hardwood, size class 3 (pole-size trees), canopy covers P (open) and M (moderate); and valley-foothill hardwood, size class 4 (small trees), canopy covers M and D. Classification of the various study sites followed the WHR vegetation guidelines (Mayer and Laudenslayer 1988). Chaparral sites were grouped according to criteria developed by England (1988). Characteristics of the chaparral sites surveyed are given in Table 1.

In comparing the WHR printouts to the Pinnacles data set, we used only observations obtained during variable circular plot counts on our study sites. Furthermore, observations were limited to no more than 50 m distance to ensure that sampling occurred within the correct habitat type. Only species appropriately censused by the variable circular plot technique were used. Thus, hawks, owls, poorwills, herons, and egrets were excluded. Before making comparisons, we checked WHR printouts against species distribution maps (Grenfell and Laudenslayer 1983) to ensure that each species was in western San Benito County. This eliminated only a few species from the analysis.

Our primary concern was the first level predictions of presence or absence, with an emphasis on determining how well the WHR models predicted species composition of the bird communities at Pinnacles National Monument. To this end, omissions from the WHR lists of species found at the Monument are considered more serious than are the presence of species on the list that do not occur at Pinnacles.

In analyzing data, we first looked at the proportion of bird species recorded in the field that were predicted to occur by WHR. Observations made, but not predicted, provided a measure of "errors of omission." Species listed on the printout were compared to those recorded during the field surveys. The proportion not recorded in the field was the index for "errors of commission."

Recommendations for changes to the WHR data base are based on the relative abundance of the species in each habitat type. We recommended a species be added if we recorded it at least twice. We felt that a species should be deleted if we did not record it in the habitat type in question but did record it in other habitats.

TABLE 1. Vegetation Characteristics of Chaparral Sites Surveyed in Pinnacles National Monument During this Study. Totals are Means and Numbers in Parentheses are ± 1 S.D.

	% Total shrub cover	*% Crown* decadence	%Absolute cover	
			Adenostema	*Ceanothus*
Chamise Chaparral-4,M (senescent w/moderate canopy cover)				
Site 1	65.3	42.9	46.7	18.7
2	47.7	48.1	41.3	0
3	48.7	59.5	48.7	0
	53.9(±9.9)	50.2(±8.5)	45.6(±6.8)	6.2(±10.8)
Chamise Chaparral-4,D (senescent w/ dense canopy cover)				
Site 4	99.0	39.0	54.7	44.3
5	103.7	35.7	70.0	33.7
6	108.0	47.9	62.7	38.3
7	80.3	51.1	70.7	9.7
8	91.3	43.2	72.7	18.7
9	75.3	61.5	50.3	25.0
10	111.3	54.8	87.0	24.3
11	70.7	48.3	55.7	15.0
12	114.7	54.5	61.0	53.7
	94.9(±16.3)	48.4(±8.2)	65.0(±11.4)	29.2(±14.4)
Mixed Chaparral-4,D (senescent w/dense canopy cover)				
Site 13	91.7	42.2	0	42.7[a]
14	111.7	43.5	0	61.0[a]
15	91.3	42.4	0	0[b]
16	123.7	38.3	0	34.0[b]
17	90.7	59.5	22.7	11.3[c]
18	136.7	46.3	42.7	94.0
19	126.0	40.7	11.0	40.3
	110.3(±19.2)	44.7(±7.0)	10.9(±16.5)	40.5(±31.2)

[a] *Quercus dumosa* was the other principal shrub species.
[b] *Fraxinus dipetela* and *Prunus ilicifolia* were the major shrub species.
[c] *Arctostaphylos glauca* was the most abundant shrub species.

RESULTS

The following is our interpretation of survey data compared to predictions from the WHR models. Habitat types serve as the main headings, and each includes short descriptions of our findings during "winter" and "spring" separately.

Chamise-Redshank Chaparral (senescent with moderate canopy cover; 3 sites)

Winter

We recorded 16 species, of which 14 (88%) were also predicted by the WHR data base (Table 2). Plain titmouse (our eighth most common species) and lesser goldfinch were missing species (Table 3). WHR listed 28 winter species, of which 14 were on our list. Of the 14 species not recorded, eight were attributed to insufficient sampling. However, we feel that the remaining six

TABLE 2. Summary of Comparison Between Field Observations and the WHR Predictions of Bird Species Composition in Various Habitat Types at Pinnacles National Monument, California.

	Errors of omission				*Errors of commission*			
	Species found in the field		*% not on WHR data base*		*Species on WHR data base*		*% not found in the field*	
Habitat type	*W*	*S*	*W*	*S*	*W*	*S*	*W*	*S*
Chamise Red-shank Chaparral (4,M), senescent, moderate canopy cover	16	20	12	30	28	32	21	22
Chamise Red-shank Chaparral (4,D), senescent, dense canopy cover	21	28	48	46	18	24	39	29
Mixed chaparral, senescent (4,D), dense canopy cover	17	27	24	41	28	32	25	12
Valley-Foothill Hardwood (3,P), pole-sized trees, open canopy cover	23	40	4	7	55	64	0	0
Valley-Foothill Hardwood (3,M), pole-sized trees, moderate canopy cover	24	39	21	13	43	50	7	0
Valley-Foothill Hardwood, (4,M), small trees, moderate canopy cover	22	31	18	6	46	54	6	2
Valley-Foothill Hardwood (4,D), small trees, dense canopy cover	23	36	48	50	32	35	12	0

W = Winter (December–February); S = Spring (March–June)

species (wild turkey, house wren, phainopepla, loggerhead shrike, European starling, and yellow-rumped warbler) were inappropriately included in this habitat type and should be deleted from the WHR data base (Table 4).

Spring

We recorded 20 species, 14 (70%) of which were also listed on WHR (Table 2). Two of the species omitted, plain titmouse and rufous-crowned sparrow, were among the birds that we most frequently recorded in this habitat and should be added to WHR (Table 3). The golden-crowned sparrow should also be added as it is common into late April even though it does not breed in the park. Of the 32 spring species on the WHR printout, we felt that all but seven were appropriate for the habitat. Questionable species were wild turkey, house wren, Swainson's thrush, phainopepla, loggerhead shrike, European starling, and Wilson's warbler; all should be deleted (Table 4).

Chamise-redshank Chaparral (senescent with dense canopy cover; 9 sites)

Winter

We recorded 21 species, 11 (52%) of which were also on the WHR list (Table 2). Species not listed included our second (plain titmouse) and tenth (brown towhee) most common species (Table 3). WHR listed 18 winter

TABLE 3. The Following Species Should be Added to the WHR Species List for the Seasons Indicated.

Chaparral

Chamise red-shank, senescent, moderate canopy cover	*Chamise red-shank, senescent, dense canopy cover*	*Mixed chaparral, senescent, dense canopy cover*
PLTI (yl)	PLTI (yl)	PLTI (yl)
LEGO (yl)	LEGO (yl)	LEGO (yl)
GCSP (fs)	GCSP (fs)	GCSP (fs)
	BHGR (s)	
RCSP (yl)		
	CAQU (yl)	CAQU (yl)
	MODO (s)	
	NOFL (yl)	
		WEFL (s)
		WWPE (s)
		CNWR (yl)
	WEBL (s)	WEBL (yl)
	WCSP (fs)	WCSP (fs)
	BRTO (yl)	BRTO (yl)
	HETH (fs)	
	HUVI (fs)	
	VGSW (s)	

Valley-Foothill Hardwood

Pole-sized trees, open canopy	*Pole-sized trees, moderate canopy*	*Small trees, moderate canopy*	*Small trees, dense canopy*
YRWA (fs)	YRWA (fs)		YRWA (fs)
			PUFI (yl)
			LEGO (yl)
		GCSP (fs)	GCSP (fs)
			CAQU (yl)
			MODO (s)
			VGSW (s)
	WEBL (yl)		WEBL (yl)
	BRTO (yl)	BRTO (yl)	BRTO (yl)
		CATH (l)	CATH (yl)
			WETA (s)
			ATFL (s)
			RCKI (fs)
			BGGN (s)
			WREN (yl)
			BEWR (yl)
			RSTO (yl)

yl = yearlong; fs = fall–spring; s = spring

species, of which we judged seven (wild turkey, white-throated swift, Nuttall's woodpecker, house wren, northern mockingbird, phainopepla, and yellow-rumped warbler) inappropriate for the habitat, and these should be deleted from WHR data base (Table 4).

Spring

We recorded 28 species, of which 15 (54%) were also on the WHR list (Table 2). Omitted species included our fourth (plain titmouse), ninth (lesser goldfinch), and tenth (brown towhee) most common species (Table 3). Of the 24 species listed by the WHR model, all were appropriate except the wild turkey, white-throated swift, nuttall's woodpecker, house wren, Swainson's thrush, northern mockingbird, and phainopepla (Table 4).

TABLE 4. The Following Should be Deleted from the WHR Species List for the Seasons Indicated.

Chaparral		
Chamise red-shank, senescent, moderate canopy cover	*Chamise red-shank, senescent, dense canopy cover*	*Mixed chaparral, senescent, dense canopy cover*
WITU (yl)	WITU (yl)	WITU (yl)
PHAI (yl)	PHAI (yl)	PHAI (yl)
EUST (yl)		EUST (yl)
LOSH (w)		
SWTH (s)	SWTH (s)	SWTH (s)
HOWR (s)	HOWR (yl)	
YRWA (fs)	YRWA (fs)	YRWA (fs)
WIWA (s)		
		BTPI (yl)
		CEWA (yl)
		GCKI (w)
	WTSW (yl)	
	NOMO (yl)	
	NUWO (yl)	

Valley-Foothill Hardwood			
Pole-sized trees, open canopy	*Pole-sized trees, moderate canopy*	*Small trees, moderate canopy*	*Small trees, dense canopy*
OCWA (w)	OCWA (w)	OCWA (w)	OCWA (w)
TOWA (w)	TOWA (w)	TOWA (w)	TOWA (w)
BHCO (w)	BHCO (w)	BHCO (w)	BHCO (w)
LASP (w)			
	SWTH (s)		
			HOWR (w)
WTSW (yl)	WTSW (yl)	WTSW (yl)	WTSW (yl)

yl = yearlong; w = winter; fs = fall-spring; s = spring

Mixed Chaparral (senescent with dense canopy cover; 7 sites)

Winter

There were 17 species on our winter list, and 13 (76%) were contained in the WHR database (Table 2). Species omitted included our fifth most commonly detected bird, the plain titmouse. Other omitted species were the California quail and golden-crowned sparrow (Table 3). The WHR model listed 28 winter species, 21 of which were either on our list or were considered appropriate species for the habitat. Seven remaining species were deemed inappropriate: wild turkey, band-tailed pigeon, golden-crowned kinglet, cedar waxwing, phainopepla, European starling, yellow-rumped warbler (Table 4).

Spring

Of 27 species, 16 (59%) were also on the WHR printout (Table 2). Two of our ten most common species (plain titmouse and lesser were omitted from WHR (Table 3). Only four of the 32 spring species on the WHR printout seemed inappropriate: wild turkey, Swainson's thrush, phainopepla, and European starling (Table 4).

Valley-Foothill Hardwood (pole-sized trees and open canopy; 4 sites)

Winter

We recorded 23 species, and all but one were predicted by the WHR data base (Table 2). The lone exception, the black phoebe, was detected only once. There were 55 species listed on the WHR printout, many of which do not occur at Pinnacles with sufficient frequency to be recorded during our counts (e.g., Lewis' woodpecker, yellow-billed magpie, cedar waxwing, loggerhead shrike), but which can be considered legitimate species in the habitat.

Spring

Of 40 recorded species, 37 (92.5%) were also on the WHR list (Table 2). Omissions included the yellow-rumped warbler, our eighth most frequently recorded species, and two species (purple finch and western tanager) recorded once each. Several species on the WHR list were observed only once in the field: Acorn woodpecker, blue-gray gnatcatcher, California quail, Lawrence's goldfinch, Steller's jay, and warbling vireo.

Unrecorded were 27 of the 64 species included on the WHR printout for the spring season. As in the winter, all missing species are reasonable for the habitat type.

Valley-Foothill Hardwood (pole-sized trees and moderate canopy cover; 4 sites)

Winter

In this habitat type, we recorded 24 species, 19 (79%) of which were also on the WHR printout (Table 2). Two of the missing species (golden-crowned and rufous-crowned sparrows) were recorded one time each. WHR listed 43 species, 40 of which were either on our list or appropriate for this habitat type. Three remaining species (orange-crowned warbler, Townsend's warbler, and brown-headed cowbird) were erroneously listed as occurring in the winter.

Spring

Of the 39 species on our list, 34 (87.2%) were listed on the WHR printout (Table 2). Of the five missing species, the lark sparrow and the California thrasher were each recorded only one time, but the western bluebird was among our 10 most frequently recorded species. All 50 species on the WHR list, were appropriate.

Valley-Foothill Hardwood (small trees with moderate canopy cover; 3 sites)

Winter

We recorded 22 species, and 18 (82%) were also on the WHR list (Table 2). Four omissions were the brown towhee (our fifth most common species); California thrasher (2 records); golden-crowned sparrow and canyon wren (one record each). All except the latter should be added to WHR (Table 3). WHR listed 46 winter species for this habitat. Only 18 of these match our list, while 18 others were recorded in oak woodland habitat sometime during the study period. However, in over two years of field work, we never recorded the following species in any of the oak woodland habitats: Lewis' woodpecker, yellow-billed magpie, common raven, golden-crowned kinglet, loggerhead shrike, American goldfinch, and house sparrow. All except the raven are rarely recorded in the Monument. The raven is a common species at Pinnacles, but evidently rarely uses the oak woodland habitat. The remaining three species should not be included in the WHR winter species list: orange-crowned warbler, Townsend's warbler, brown-headed cowbird.

Spring

Thirty-one species were recorded. Two of these were not on the WHR list: the brown towhee, our seventh most common species, and the western tanager, recorded once. There were 54 species on the WHR printout of which we recorded 29. Seven species are seldom, if ever, recorded at Pinnacles

National Monument, and 17 others were recorded in the habitat during the study but not during the actual count periods. The Swainson's thrush was found only in mixed riparian woodlands.

Valley-Foothill Hardwood (small trees with dense canopy cover; 3 sites)

Winter

There were 23 species on our list, but just 12 (52%) were included in the WHR database (Table 2). Omitted species were: Bewick's wren (our third most common species); rufous-sided towhee (fourth-ranked species); brown towhee (fifth-ranked species); California thrasher (our sixth most common species); western bluebird (the seventh-ranked species); golden-crowned sparrow, wrentit, ruby-crowned kinglet (two records each); California quail, fox sparrow, and lesser goldfinch (one record each). All of these species should be added to the WHR data base (Table 3). Of the 32 species on the WHR list, 12 were also on our list; 16 others were suitable for inclusion, but were too uncommon to be recorded during our counts. Four species do not belong: the white-throated swift is a cliff-nesting species that may occasionally fly over, but which is not a woodland species; orange-crowned and Townsend's warblers and brown-headed cowbird are not winter species at Pinnacles (Table 4).

Spring

As in the winter, there was poor agreement between our field observations and WHR data base predictions. Of 36 recorded species, only 18 (50%) were included in the WHR data base (Table 2). Among the missing species were our 3rd, 4th, 5th, and 6th most commonly observed species, respectively: Violet-green swallow, rufous-sided towhee, Bewick's wren, and western bluebird (Table 3). There were 35 species on the WHR list, and although we recorded only 18 during our surveys, the remaining are legitimate oak woodland species.

DISCUSSION

There are presently few published validations of California WHR habitat models. Verner (1980) and Dedon et al. (1986) tested mixed-conifer habitat types, mixed-evergreen was tested by Raphael and Marcot (1986), black oak (*Q. kelloggii*) by Dedon et al. (1986), and chaparral by England and Anderson (1985). Results of these validation tests have been variable. In each instance the model predicted occurrence of species well, but the studies suggest that considerable revision will be necessary to improve performance in predicting relative abundances in habitat stages.

We believe that two simple indices can be used to assess the ability of the WHR data base to predict the presence of a species in a specific habitat type. The first presents the percentage of species recorded in the field but not included in the data base. The second measure is the percentage of species listed in the data base but not noted in the field. The first index measures the frequency of "errors of omission", species that should be on the data base but are not. The second is a measure of the "errors of commission", species that are incorrectly included in the data base. Errors of commission are to be expected, given that information in the data base was derived from various sources and studies at different locations and times. When compared to data from any given place and time, there is bound to be an excess of species. Increased sampling at more locations or over longer time periods will probably decrease the number of extra species and thereby lower the WHR errors of commission.

Errors of omission, on the other hand, reflect directly on the completeness of the data base and on its validity as a model of actual wildlife-habitat relationships. Given that we classified the habitat correctly and that the field data were reliably collected, a high frequency of missing species suggests either a lack of historical information in that habitat and/or location being considered, or a failure in the compilation of the existing WHR information. Neither option provides much consolation for a user who is trying to determine what species to expect in an area.

Our analysis revealed considerable variability among habitat types in errors of omission. Values ranged from 4% to 48% in the winter and 6% to 50% in the spring (Table 2). The best predictions occurred in the valley-foothill hardwood habitat for pole-sized trees with open and moderate canopy cover, and small trees with moderate canopy cover. These habitat types may be more widely studied or more common than the others that we tested, thus resulting in a more complete listing in the WHR data base.

The very poor predictive performance in the valley-foothill hardwood dense-canopied oak woodland may be due to the scarcity of this mature habitat, especially stands with a shrub understory. Several of the species found in this study, but not on the WHR data base, favor shrubs and brushy ground cover (e.g., California quail, California thrasher, Bewick's wren, wrentit, rufous-sided towhee, brown towhee, golden-crowned sparrow, and fox sparrow). Conceivably, most of the data in the WHR system are from studies in grazed oak woodlands where there is little or no understory. At Pinnacles, our study sites were virtually free from grazing pressure, and had healthy understory components. In this respect, the oak woodlands at Pinnacles National Monument may now be atypical, reflecting a woodland habitat structure that formerly was widespread in California but is no longer prevalent due to changing land use practices.

We found that chaparral communities were also characterized by relatively high rates of both types of errors (Table 2), as did England and Anderson (1985). This result is probably due to the lack of historical information on the bird communities in these habitat types. The published studies of chaparral birds with which we are familiar are all from southern California and none was conducted in mature, senescent stands of chaparral. Furthermore, most previous studies of chaparral birds have not considered the nonbreeding season. If the information in the WHR system was obtained from these sources, it is not surprising that there was poor agreement with field observations.

We recommend a number of additions to the WHR data base, particularly in the chamise and mixed chaparral and valley-foothill hardwood dense canopy habitat types (Table 3). These are based solely on field observations and represent a conservative list, in that we did not include species with just one record in a habitat type. Several species are recommended additions in three or more or the habitat types: Golden-crowned sparrow, brown towhee, lesser goldfinch, California quail, and western bluebird. These are all common species and, except for the golden-crowned sparrow, are yearlong residents in our study area.

The list of recommended deletions from the data base is small and is confined mainly to the chaparral habitat types (Table 4). Our justification for recommending the deletions in the chaparral habitats is that we did not record the species in chaparral but did record them in other habitats within the study area. Although there were many species on the WHR data base for the valley-foothill hardwood habitats that we did not record in the field, there was no justification for deleting them as they undoubtedly use these habitat types elsewhere.

Overall, the analysis presented here was conservative. Had all of the species listed on the WHR printouts been included in the analysis, the errors of commission would have been much greater. Even so, there were still high errors of omission levels (greater than 20%) in five of the seven habitat types that we assessed. Similar results have been reported by others (England and Anderson 1985, Dedon et al. 1986, Raphael and Marcot 1986), using more detailed analyses. Together, these findings point to the need for further field evaluations and refinement of the WHR system. Moreover, potential users should be cautioned that, at present, the WHR data base may not adequately predict species composition for some locations and habitat types.

It seems imperative that the shortcomings in the WHR data base be identified as soon as possible, and that steps be taken to improve the predictive capability of the system. A first step might be to look at those habitat/location combinations for which published information is lacking. Such a situation certainly applies to mature chaparral. More may be known about birds in oak woodlands but, as mentioned previously, perhaps most studies in hardwoods have been conducted on rangeland with little or no shrub layer.

Some discrepancies are consequences of the species range maps. The violet-green swallow and chipping sparrow are each depicted with non-overlapping winter and spring ranges in San Benito County. Thus, these species are labeled yearlong in location even though at a given site within the county, Pinnacles for instance, the birds are present for just a portion of the year. The effect of inaccurate range maps leads to an increase in errors of commission. For the house wren, the eastern edge of San Benito County shows year-round residency, while 95% is summer only. The WHR printout gives yearlong as season in this location. The fox sparrow, golden-crowned sparrow, and white-crowned sparrow are shown as being winter (October–February) residents in San Benito County, even though they remain through April, at least at Pinnacles. This type of discrepancy incurs errors of omission when comparing the spring bird communities. The depicted ranges of the Townsend's solitaire and western tanager do not include San Benito County at all, yet both species do occur at Pinnacles, and the tanager is fairly common. Conversely, the yellow-bellied sapsucker and the mountain chickadee are on the printout even though their range maps do not include San Benito County. Townsend's warbler is shown as a winter resident, but occurs only in the spring and summer at Pinnacles.

Careful screening of all species range maps is time-consuming, but can help eliminate discrepancies such as those described above, and thereby reduce the error rate calculated for the system. Other reasons can be proposed for the lack of concordance between field observations and system predictions. For example, "The field study was not performed over a sufficiently long time span", or "The data available for incorporation into the system are not sufficiently complete to cover the field situation". However, regardless of their merit, reliance on *ad hoc* explanations to account for the shortcomings of the system is unprofitable, does not correct the identified problems, and will not convince others to use the product.

Our validation test of the California WHR species-habitat models suggests certain trends that future users should seriously consider. It appears that at a very gross level (e.g., predicting presence or absence) the WHR data base performs reasonably well in habitats that are well represented throughout the state. However, in those habitats that presently have a limited distribution (e.g., closed canopy oak woodland with understory) a number of inaccuracies appear. The chaparral habitats also performed poorly, indicating that the reliability of the WHR model may vary greatly among habitat types. Moreover, habitat suitability predictions seem to be generally poor. Therefore, potential users should be cognizant that gross level predictions are more reliable than are those dealing with minor habitat modifications.

Given the variable rates of agreement between predicted and observed community bird species lists in this study, and those reported elsewhere, it would be unwise to take a passive approach to validation of the California WHR system by waiting for interested parties to submit their field data and recommendations. Rather, an active approach is needed through which problem areas are identified and on-going research sought, or new studies initiated, to fill existing information gaps.

SUMMARY

Using data obtained during bird community surveys at Pinnacles National Monument in the winter and spring of 1984 and 1985, we evaluated the accuracy of predictions made by the California Wildlife-Habitat Relationships (WHR) data base. We used the variable circular plot technique to compile lists of species in the field, and compared these with species lists generated by the WHR system for habitat types in chamise-redshank chaparral, mixed chaparral, and valley-foothill hardwoods.

Two classes of discrepancies were recognized: (i) "errors of commission" (species listed by the data base but not recorded in the field), and (ii) "errors of omission" (species recorded in the field but not listed by the data base). The occurrence of errors of commission is not surprising given that the information in the data base was derived from various sources and studies at different locations and times. When compared with data from a given place and time, it is reasonable to expect an excess of species. On the other hand, errors of omission reflect directly on the completeness of the data base and on its validity as a model of actual wildlife-habitat relationships.

We found considerable variability among habitat types in both types of errors. The valley-foothill hardwood had few errors of commission, but errors of omission averaged 22% in the winter and 19% in the spring. Errors of commission in the chaparral habitat types ranged from 12% to 39%. Among the three chaparral types, errors of omission ranged from 12% to 48% in the winter and 30% to 46% in the spring.

In order for the WHR system to operate effectively, it must accurately predict the occurrence of species by habitat type, geographic location, and season. To date, the capability of the system to do this consistently has not been demonstrated. Our findings indicate that additional effort needs to be directed toward improving the accuracy of the first-level WHR models.

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Editor's Note: The Wildlife Habitat Relationships data base, housed within the Department of Fish and Game, is an integral part of a dynamic system, the goal of which is to provide more effective tools for the management of wildlife in California. This data base is periodically updated in response to studies such as the one presented here and the ongoing efforts of the California Interagency Wildlife Task Group. Significant revisions of the avian models in the data base have been recently completed as have revisions of species distribution maps. Similar efforts for mammals, reptiles, and amphibians are currently underway.

APPENDIX I

Species Code, Common, and Scientific Names of Birds Mentioned in this Paper.

Species Code	*Common Name*	*Scientific Name*
ACWO	acorn woodpecker	*Melanerpes formicivorus*
AMGO	American goldfinch	*Carduelis tristis*
ATFL	ash-throated flycatcher	*Myiarchus cinerascens*
BEWR	Bewick's wren	*Thryomanes bewickii*
BGGN	blue-gray gnatcatcher	*Polioptila caerulea*
BHCO	brown-headed cowbird	*Molothrus ater*
BHGR	black-headed grosbeak	*Pheucticus melanocephalus*
BLPH	black phoebe	*Sayornis nigricans*
BRTO	brown towhee	*Pipilo fuscans*
BTPI	band-tailed pigeon	*Columba fasciata*
CATH	California thrasher	*Toxostoma redivivum*
CAQU	California quail	*Callipepla californica*
CEWA	cedar waxwing	*Bombycilla cedrorum*
CHSP	chipping sparrow	*Spizella passerina*
CNWR	canyon wren	*Catherpes mexicanus*
CORA	common raven	*Corvus corax*
EUST	European starling	*Sturnus vulgaris*
FOSP	fox sparrow	*Passerella iliaca*
GCKI	golden-crowned kinglet	*Regulus satrapa*
GCSP	golden-crowned sparrow	*Zonotrichia atricapilla*
HETH	hermit thrush	*Catharus guttatus*
HOSP	house sparrow	*Passer domesticus*
HOWR	house wren	*Troglodytes aedon*
HUVI	Hutton's vireo	*Vireo huttoni*
LAGO	Lawrence's goldfinch	*Cardeulis lawrencei*
LASP	lark sparrow	*Chondestes grammacus*
LEGO	lesser goldfinch	*Carduelis psaltria*
LEWO	Lewis' woodpecker	*Melanerpes lewis*
LOSH	loggerhead shrike	*Lanius ludovicianus*
MOCH	mountain chickadee	*Parus gambeli*
MODO	mourning dove	*Zenaida macroura*
NOFL	northern flicker	*Colaptes auratus*
NOMO	northern mockingbird	*Mimus polyglottos*
NUWO	Nuttall's woodpecker	*Picoides nuttallii*
OCWA	orange-crowned warbler	*Vermivora celata*
PHAI	phainopepla	*Phainopepla nitens*
PLTI	plain titmouse	*Parus inornatus*
PUFI	purple finch	*Carpodacus purpureus*
RCKI	ruby-crowned kinglet	*Regulus calendula*
RCSP	rufous-crowned sparrow	*Aimophila ruficeps*
RSTO	rufous-sided towhee	*Pipilo erythrophthalmus*
STJA	Steller's jay	*Cyanocitta stelleri*
SWTH	Swainson's thrush	*Catharus ustulatus*
TOSO	Townsend's solitaire	*Myadestes townsendi*
TOWA	Townsend's warbler	*Dendroica townsendi*
VGSW	violet-green swallow	*Tachycineta thalassina*
WAVI	warbling vireo	*Vireo gilvus*
WCSP	white-crowned sparrow	*Zonotrichia leucophrys*
WEBL	western bluebird	*Sialia mexicana*
WEFL	western flycatcher	*Empidonax difficilis*
WETA	western tanager	*Piranga ludoviciana*
WIWA	Wilson's warbler	*Wilsonia pusilla*
WITU	wild turkey	*Meleagris gallopavo*
WREN	wrentit	*Chamaea fasciata*
WTSW	white-throated swift	*Aeronautes saxatalis*
WWPE	western wood pewee	*Contopus sordidulus*
YBMA	yellow-billed magpie	*Pica nuttalli*
YBSA	yellow-bellied sapsucker	*Sphyrapicus varius*
YRWA	yellow-rumped warbler	*Dendroica coronata*

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ORGANOCHLORINES, MERCURY, AND SELENIUM IN WINTERING SHOREBIRDS FROM WASHINGTON AND CALIFORNIA [1]

THOMAS W. CUSTER
U.S. Fish and Wildlife Service
Patuxent Wildlife Research Center
Gulf Coast Field Station
P.O. Box 2506
Victoria, Texas 77902

and

J. P. MYERS [2]
The Academy of Natural Sciences of Philadelphia
19th and the Parkway
Logan Square
Philadelphia, Pennsylvania 19103

Dunlins *Caldris alpina,* and black-bellied plovers, *Pluvialis squatarola,* were collected in Washington and California during the winter of 1984–85; long-billed dowitchers, *Limnodromus scolopaceus,* were collected in California. Pooled breast muscles (by species, location, and date) were analyzed for organochlorines and pooled livers for mercury and selenium. DDE was detected in all eight dunlin, three of five dowitcher, and two of nine plover muscle pools. Estimated DDE concentrations in dunlin carcasses at two sites in California were greater than 3 ppm wet wt, a dietary concentration associated with eggshell thinning and decreased reproductive success in raptors. Detectable concentrations of mercury and selenium were found in all liver pools. Selenium concentrations in plovers from two sites in Washington were elevated (26.9 and 29.9 ppm dry wt), but below concentrations shown to affect reproductive success in black-necked stilts, *Himantopus mexicanus.* Elevated mercury concentrations in livers of dunlin from Bodega Bay (18.9 ppm dry wt) and Salinas River (16.3 ppm dry wt), California were below levels associated with acute toxicity.

INTRODUCTION

DDE, the major metabolite of the pesticide DDT, was implicated in the population decline of falcons in North America and Europe (Fox 1971, Peakall 1976). Migratory shorebirds had the highest body burdens of organochlorines among the prey items of breeding falcons in North America (Cade, White, and Haugh 1968; Endersen and Berger 1968; White, Emison, and Williamson 1973; Walker 1977). Because the Pacific coast of Washington is a major shorebird wintering area and predation on shorebirds by falcons is common there, wintering shorebirds along the Pacific coast were collected in 1980–81 and analyzed for organochlorine contaminants (Schick et al. 1987). Organochlorine concentrations in shorebirds collected from western Washington in 1980–81 were below levels suspected to affect falcon survival or reproduction (Schick et al. 1987). A sample of sanderlings, *Calidris alba*, from Bodega Bay, California had relatively high DDE residues (mean = 1.7 ppm wet wt, maximum = 32 ppm) but this was the only species and location sampled in California (Schick

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[2] Present address: National Audubon Society, 950 Third Avenue, New York, NY 10022.

et al. 1987). Mercury and selenium can also have acute or chronic effects on wildlife (Ohlendorf 1989 and reviews by Eisler 1985, 1987); little information, however, is available for concentrations of these elements in Pacific coast shorebirds (e.g., White et al. 1987).

Our objective was to evaluate, based on tissue concentrations, the likelihood of effects of contaminants on shorebirds and raptors that feed on them at selected sites in Washington and California. During the winter of 1984–85 we obtained tissues of shorebirds that were collected in Washington and California for various biological investigations. We analyzed available tissues for organochlorines, mercury, and selenium.

METHODS

Dunlins, long-billed dowitchers, and black-bellied plovers were collected by shotgun from 30 November 1984 through 1 March 1985 in Washington and California (Table 1). During this period, the shorebirds represent resident wintering populations (Pienkowski and Pienkowski 1983, Brennan et al. 1985). The collected birds were placed in plastic bags, labeled, and placed on dry ice. Later they were transferred to a freezer.

Carcasses were prepared by skinning the birds and removing the feet, head, wingtips, and gastrointestinal tracts. One-half of the breast muscle was removed, pooled with similar samples (by species, location, and date), wrapped in aluminum foil, and refrozen until analysis. The carcasses of four pools (Table 2) minus the removed breast muscle were also wrapped in aluminum foil, sealed in a plastic bag, and refrozen. Muscle samples were used primarily because carcass tissues were also required for other studies.

The muscle and carcass samples were analysed for organochlorine contaminants at Patuxent Wildlife Research Center, Laurel, Maryland, following methods described by Cromartie et al. (1975) and Kaiser et al. (1980). The lower limit of detection was 0.1 ppm for pesticides (p,p'DDT, p,p'DDE, p,p'DDD, dieldrin, endrin, toxaphene, heptachlor epoxide, *cis*-chlordane, *cis*-nonachlor, oxychlordane, *trans*-nonachlor) and 0.5 ppm for polychlorinated biphenyls (PCBs) on a wet wt basis.

For the four paired carcass-muscle samples, breast muscle residues and lipid wt were added to carcass samples to obtain a total value for carcass. Based on the mean carcass to muscle DDE ratio for four samples of 2.2 (Table 2), we estimated organochlorine concentrations in carcasses by doubling values for muscle (Table 1).

The left lobe of the liver was removed, pooled with similar samples (by species, location, date), placed in a chemically-clean jar and refrozen prior to analysis. The remainder of the liver was used for other studies. The liver tissues were analyzed for mercury as described by Haseltine et al. (1981). Selenium analyses were performed on a 0.5 g portion of sample as described by Krynitsky (1987). The lower limit of detection was 0.02 ppm for mercury and 0.05 ppm for selenium on a wet wt basis; concentrations of these two elements are presented on a dry wt basis in order to make comparisons with other values in the literature (e.g., Ohlendorf et al. 1986). Approximate conversions to wet wt concentrations are possible by using the average percent moisture of 68.6% (Table 1).

TABLE 1. Concentrations of DDE and PCBs (ppm wet wt) in Breast Muscles and Selenium and Mercury (ppm dry wt) in Livers of Three Shorebird Species Wintering in Washington and California.

Species	Location	Date	% lipid	Muscle ppm (wet wt) DDE	Muscle ppm (wet wt) PCB	Liver[a] ppm (dry wt) Se	Liver[a] ppm (dry wt) Hg	Number in pool	Sex[b] M/F	Age[b] A/J
Dunlin	Grays Harbor, WA	16–22 Dec 84	4.2	0.3	nd	15.2	4.2	10	5/5	5/5
	Grays Harbor, WA	12–28 Feb 85	3.4	0.4	nd	20.2	4.4	10	7/3	3/5
	Humboldt Bay, CA	10 Dec 84	4.1	1.9	0.5	16.2	5.5	10	9/1	10/0
	Humboldt Bay, CA	2 Feb 85	2.3	0.6	nd[c]	13.6	9.8	5	3/1	2/2
	Salinas River, CA	26 Jan 85	1.2	1.2	nd	7.0	16.3	2	1/1	1/1
	Bodega Bay, CA	30 Nov–4 Dec 84	1.2	3.5	1.1	11.7	18.9	4	2/2	0/4
	Bodega Bay, CA	15–16 Jan 85	3.3	1.8	0.9	9.5	6.6	17	8/3	10/5
	Morro Bay, CA	23–24 Jan 85	3.4	1.4	nd	12.2	10.5	10	2/8	5/5
Long-billed Dowitcher	Humboldt Bay, CA	10–14 Dec 84	3.7	nd	nd	8.3	3.3	9	5/4	0/9
	Humboldt Bay, CA	5 Feb 85	3.7	nd	nd	5.5	2.5	9	2/7	4/5
	Sacramento NWR, CA	29 Jan 85	4.6	1.1[d]	nd	11.1	2.8	10	8/2	4/6
	Delevan NWR, CA	30 Jan 85	3.6	1.3[e]	nd	15.3	2.1	10	4/6	8/2
	Morro Bay, CA	22–25 Jan 85	1.9	0.4	nd	14.1	2.7	10	2/8	3/7
Black-bellied Plover	Samish Bay, WA	20–21 Dec 84	5.1	0.4[f]	nd	29.9	0.7	5	1/4	5/0
	Kennedy Creek, WA	28 Feb–1 Mar 85	2.5	nd	nd	26.9	0.9	6	4/2	4/1
	Grays Harbor, WA	4 Dec 84	3.6	nd	nd	11.7	1.0	6	0/0	0/0
	Grays Harbor, WA	12–14 Feb 85	3.0	nd	nd	9.4	0.8	10	6/4	9/1
	Humboldt Bay, CA	10–14 Dec 84	4.8	nd	nd	9.9	1.0	9	4/4	6/3
	Humboldt Bay, CA	1–5 Feb 85	4.4	nd	nd	5.8	1.0	9	6/3	7/1
	Bodega Bay, CA	1–2 Dec 84	3.0	nd	nd	9.3	1.7	4	2/2	4/0
	Bodega Bay, CA	8–15 Jan 85	4.1	nd	nd	7.5	1.8	6	2/3	5/1
	Morro Bay, CA	22 Jan 85	2.1	0.4	1.0	7.5	4.2	6	4/2	4/2

[a] Mean % moisture = 68.6, range = 64.2 – 71.8
[b] Some samples with age or sex unknown
[c] nd = not detected
[d] Sample includes 0.1 ppm DDD
[e] Sample includes 0.2 ppm DDD
[f] Sample includes 0.1 ppm DDT, 0.1 ppm HCB, 0.2 ppm pentachlorobenzene

TABLE 2. Percent Lipid and DDE Concentration (ppm wet wt) in Muscle and Carcasses of Dunlin and Long-billed Dowitchers. One-half of the Breast Muscle was Removed from Each Carcass to Form the Pooled Muscle Sample.

Species	*Location*	*Date*	*Number in pool*	*% Lipid* Muscle	*% Lipid* Carcasses	*% Lipid* Ratio[a]	*DDE ppm (wet wt)* Muscle	*DDE ppm (wet wt)* Carcass	*DDE ppm (wet wt)* Ratio
Dunlin	Grays Harbor, WA	12/84	10	4.2	8.1	1.9	0.2	0.5[b]	2.5
Dunlin	Grays Harbor, WA	2/85	10	3.4	4.2	1.2	0.4	0.9[c]	2.3
Dowitcher	Sacramento, NWR, CA	1/85	10	4.6	7.9	1.7	1.1[d]	2.4[e]	2.2
Dowitcher	Delevan, NWR, CA	1/85	10	3.6	7.3	2.0	1.3[f]	2.4[g]	1.9
		Mean		3.9	6.9	1.8	0.8	1.6	2.2

[a] carcass ÷ muscle
[b] Sample includes 0.4 ppm PCBs
[c] Sample includes 0.5 ppm PCBs
[d] Sample includes 0.1 ppm DDD
[e] Sample includes 0.4 ppm DDD
[f] Sample includes 0.2 ppm DDD
[g] Sample includes 0.4 ppm DDD, 0.2 ppm dieldrin, 0.1 ppm *trans*-nonachlor

RESULTS

DDE was detected in all eight dunlin muscle samples (range 0.3–3.5 ppm), three of five dowitcher samples (maximum 1.3 ppm), and two of nine plover samples (maximum 0.4 ppm) (Table 1). PCBs were detected in three of eight dunlin samples (maximum 1.1 ppm), in none of the five dowitcher samples, and one of nine plover samples. Dunlin collected from Bodega Bay, California in Nov.–Dec. 1984 had the highest DDE (3.5 ppm) and PCB (1.1 ppm) concentrations.

DDD was detected in dowitcher muscle samples at Sacramento National Wildlife Refuge (NWR) (0.1 ppm) and Delevan NWR, California (0.2 ppm, Table 1). The muscle samples from Samish Bay, Washington had 0.1 ppm DDT, 0.1 ppm hexachlorobenzene, and 0.2 ppm pentachlorobenzene. No other organochlorine contaminants were detected in the pooled muscle samples.

The concentrations of DDE in carcasses of four pooled samples were about twice as high (range 1.9 to 2.5 ×, mean 2.2 ×) as muscle samples from the same pool (Table 2). This probably occurred because the percent lipid in the four pooled carcasses was also about twice as high (range 1.2–2.0 ×, mean 1.8 ×) as the muscle samples.

All liver samples had detectable levels of selenium and mercury (Table 1). Selenium concentrations (dry wt) seemed similar among species (median dunlin = 12.9 ppm, dowitcher = 11.1 ppm, plover = 9.4 ppm). Mercury was higher in dunlins (median = 8.2 ppm) than dowitchers (median = 2.7 ppm) or plovers (median = 1.0 ppm). The highest concentrations (dry wt) of selenium were in plovers from Samish Bay, (29.9 ppm) and Kennedy Creek, Washington (26.9 ppm). The highest concentrations of mercury were in dunlin from Bodega Bay (18.9 ppm) and Salinas River, California (16.3 ppm).

DISCUSSION

Since our samples are composites of mixed sexes and ages, caution should be taken when making comparisons between locations, dates, or with other studies. Concentrations of contaminants in composite samples overestimate geometric mean concentrations and may mask highly contaminated individuals (DeWeese et al. 1986). In addition, contaminant concentrations may differ between sex or age (Fimreite 1974; Parslow, Thomas, and Williams 1982; DeWeese et al. 1986; Struger, Elliot, and Weseloh 1987). Even though these variables may influence mean concentrations in pools, the data are useful as a monitoring tool to evaluate geographical sites and species of concern.

Organochlorine concentrations in black-bellied plovers and dunlin collected at Grays Harbor, Washington in our study were similar to those found earlier. Two plovers collected from Grays Harbor in 1981 had 0.02 and 0.1 ppm DDE and 0.09 and 0.73 ppm PCBs (Schick et al. 1987). DDE and PCBs in plovers from Grays Harbor in our study were <0.1 and <0.5 ppm. Mean DDE and PCBs concentrations in dunlin collected in Grays Harbor in 1978–1981 were below our detection limit (0.1 and 0.5 ppm) as were PCBs in our samples; DDE, however, was 0.6–0.8 ppm in carcasses (ppm DDE in muscle × 2) from Grays Harbor in our study.

DDE concentrations in California shorebirds were generally higher than in Washington and similar to those collected in Texas. Mean DDE concentrations in dunlin carcasses collected at several sites in Washington ranged from 0.02 to 0.85 ppm (Schick et al. 1987) and 0.6 to 0.8 ppm (ppm DDE in muscle × 2) at Grays Harbor (present study). In contrast, dunlin carcasses collected in California in our study had 1.2–7.0 ppm DDE (ppm DDE in muscle × 2). Dunlin carcasses in southern Texas had 3.15 ppm DDE (White, King, and Prouty 1980). Sanderlings also had significantly higher concentrations of DDE (mean 1.7 ppm) at Bodega Bay, California than Grays Harbor (0.26 ppm); PCBs were higher at Bodega Bay (0.77 ppm) than Grays Harbor (0.38 ppm) but the differences were not significant (Schick et al. 1987). Concentrations of DDE in dowitcher carcasses collected in California in our study were <0.1–2.6 ppm (ppm DDE in muscle × 2); dowitchers from southern Texas had 2.8–5.7 ppm DDE (White, Mitchell, and Kaiser 1983).

Raptors feeding on dunlin and dowitchers at selected sites in California could be reproductively impaired by high concentrations of DDE. Peregrine falcons, *Falco peregrinus,* had 7.5% eggshell thinning and apparently reproduced normally at DDE concentrations in diets ranging from <0.01 to 1.9 ppm (White, Emison, and Williamson 1973). In contrast, diets of 3 ppm DDE thinned raptor eggshells 10–28% (Wiemeyer and Porter 1970, McLane and Hall 1972, Lincer 1975) and affected reproduction (Mendenhall, Klass, and McLane 1983). None of the plovers, two of five dowitcher and five of eight dunlin samples were above 2 ppm DDE in the carcass (muscle DDE ppm × 2); all samples greater than 2 ppm were from California. In addition, three of the eight dunlin samples were above 3 ppm DDE.

Selenium concentrations in black-bellied plovers from Samish Bay, and Kennedy Creek, Washington, were high (26.9 and 29.9 ppm dry wt) and may warrant further study. Background levels of selenium in waterbird livers, not including ducks, generally averaged less than 20 ppm dry wt (Koeman et al. 1975; Blus et al. 1977; Hutton 1981; Leonzio, Fossi, and Focardi 1986; White et al. 1987; Ohlendorf 1989). Selenium in livers of black-necked stilts collected from Kesterson NWR, California, during April to July increased from 41.8 to 94.4 ppm dry wt. During this period, selenium in livers of stilts from a nearby control area decreased from 10.7 to 5.4 ppm dry wt. At Kesterson, one-fourth of the stilt nests contained deformed young; no deformities were noted in the control area (Ohlendorf et al. 1986). In contrast, selenium in the livers of 10 bar-tailed godwits, *Limosa lapponica,* collected in the Dutch Wadden Sea varied from 20–120 ppm dry wt; there was no explanation of the origin or effects of these high levels (Goede 1985).

Dunlin in our study had higher liver concentrations of mercury (4.2–18.9 ppm dry wt) than reported earlier for this species. Concentrations of mercury in livers of dunlin were 0.47 ppm wet wt (1.55 ppm dry wt; assuming 70% moisture, Ohlendorf et al. 1986) in southern Texas (White et al. 1980), 0.7–1.3 ppm wet wt (2.3–4.9 ppm dry wt) in mercury contaminated Lake St. Clair (Dustman, Stickel, and Elder 1972), and 1.9–6.2 ppm dry wt early and late in the winter on the Wash, a relatively uncontaminated site, in eastern England (Parslow 1973).

The higher concentrations of mercury in dunlin (maximum 18.9 ppm dry wt) were not within the range associated with mortality in other birds; however, sublethal effects could occur. Birds that died of mercury toxicity generally had greater than 20 ppm wet wt (66 ppm dry wt) mercury in the liver (Borg et al. 1969; Fimreite and Karstad 1971; Koeman et al. 1975; Van Der Molen, Blok, and Graaf 1982). American black ducks, *Anas rubripes,* (Finley and Stendell 1978) and mallards, *Anas platyrhynchos,* (Heinz 1976) fed 3 ppm mercury appeared in good condition but had 11–23 ppm wet wt (36–76 ppm dry wt) mercury in their livers and lower reproductive success; mallard ducklings from these adults showed altered behavior. In contrast, mallards fed 0.5 ppm mercury had only 0.9–1.6 ppm wet wt (3.0–5.3 ppm dry wt) in liver and produced fewer ducklings than controls and the ducklings had altered behavior (Heinz 1979). Pheasants with 0.5–1.5 ppm wet wt (1.7–5.0 ppm dry wt) mercury in their livers had reduced hatching (Fimreite 1971). The latter two studies suggest sublethal effects at concentrations of mercury in many of our samples, particularly dunlin. However, most of our samples are within background levels of seabirds collected elsewhere and, as suggested earlier (Parslow, Jefferies, and Hanson 1973) seabirds may be adapted to mercury contamination.

Mercury concentrations in shorebirds were below those considered detrimental to raptors consuming them. Cockerels on a mercury-contaminated diet had 7–10 ppm wet wt (23–33 ppm dry wt) mercury in their livers; four of 12 red-tailed hawks, *Buteo jamaicensis,* died after consuming these birds for four to 12 weeks (Fimreite and Karstad 1971). Mercury concentrations in livers of dunlin at Bodega Bay and Salinas River, California were 18.9 and 16.3 ppm dry wt. Mercury liver concentrations at other locations and in other species in our study were below 10.5 ppm dry wt.

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NOTES

AN ALBINO BAT RAY, *MYLIOBATIS CALIFORNICA*, FROM THE PACIFIC COAST OF BAJA CALIFORNIA SUR, MEXICO

During June 1989, the shrimp vessel BAHIA MAGDALENA III made an exploratory fishing cruise along the Pacific coast of Baja California Sur, Mexico. Such vessels fish a pair of bottom trawls (approximately 10 m opening and mesh size 3 cm). On 18 June various hauls were made off El Ramoso, a locality on the Pacific side of Magdalena Island (which bounds the northern end of Magdalena Bay) at about 25° N. Included in the catch were a number of bat rays, *Myliobatis californica* Gill, 1865. All were of the normal dark brown on the upper side, except for one, which was an albino. This species has a distributional range from Gulf of California to Oregon (Miller and Lea 1972).

The albino is catalogued as No. 2049 in the fish collection at the Centro Interdisciplinario de Ciencias Marinas (CICIMAR) in La Paz, Baja California Sur, Mexico and is preserved in 70% ethyl alcohol. Standard length is 340 mm and disc width is 735 mm. At the time of capture the upper side was pure white, but with faint darker marks resulting from damage in the net. The color of the eyes also differed from the normal black, being yellow-orange. After fixation in formalin and subsequent preservation in alcohol the body has become grayish and the eyes have darkened to the same tone as the rest of the head region.

The fact that this albino was captured with a school of normally colored individuals suggests that the lack of pigmentation was of no disadvantage in schooling activities. Although no food was found in the digestive tract, the size of the fish was comparable to those with which it was caught, showing that albinism had not impaired feeding and growth. The fish is a female with apparently normally developed gonads.

There appear to be rather few records of albinism in batoid fishes. Traquair (1873) recorded an albino thornback ray, *Raja clavata*, and Joseph (1961) an albino cownose ray, *Rhinoptera bonasus*, but I have not found any further records. Judging by the literature, albinism is more common in sharks (e.g. Herald 1953; Herald, Schneebeli, Green, and Innes 1960; McKenzie 1970; Gopolan 1971; Talent 1973; and Cohen 1973). Presumably albinism is less disadvantageous in free-swimming fishes than in those that spend more time on or near to the substrate.

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—*Marcos de Jesus-Roldan. Laboratorio de Ictiologia. Centro Interdisciplinario de Ciencias Marinas, Apdo. postal 592; La Paz, B.C.S., Mexico.* *Accepted for publication January 1990.*

OBSERVATION OF BLACK BEAR, *URSUS AMERICANUS*, FEEDING DAMAGE TO PORT ORFORD CEDAR, *CHAMAECYPARIS LAWSONIANA*, IN DEL NORTE COUNTY, CALIFORNIA

Black bear feeding damage to coast redwood, *Sequoia sempervirens*, is not a new phenomenon and has been reported in California for over 38 years (Fritz 1951, Glover 1955, Giusti and Schmidt 1988). Authors throughout the United States have documented damage by bears to other conifer species, including white spruce, *Picea glauca* (Lutz 1949); Alaska-yellow cedar, *Chamaecyparis nootkatensis* (Hennon 1987); balsam fir, *Abies balsamea* (Zeedyk 1957); Douglas fir, *Psuedotsuga menziesii* (Maser 1967, Poelker and Hartwell 1973); and western larch, *Larix occidentalis* (Mason and Adams 1987, W. Schmidt 1987). This report is the first known documentation of black bear feeding on Port Orford cedar, *Chamaecyparis lawsoniana.*

The location of the damaged trees is in the Dominie Creek drainage, east of the town of Smith River, California. The damaged Port Orford cedar was discovered in one of three belt transects (10m × 100m) established to quantify black bear feeding damage to second growth redwood (Giusti, unpubl. data). The damaged cedar is 10.5 inches d.b.h. and stands approximately 25 feet tall. It is adjacent to the road and among a number of damaged redwoods. The feeding scars to the cedar are similar to those described by Glover (1955), Giusti and Schmidt (1988) and Giusti (1988) to coast redwood. In this case, the tree was nearly 100% girdled at its base with the bark removed upwards in long strips. Though the needles of the tree were still green, the tree was showing signs of rapid decline. Redwoods in the immediate vicinity were damaged during the spring of 1985 and 1986. Since the cedar was not marked, as were the redwoods at the time the damage occurred, the cedar was damaged at a later date. Because of the severity of the girdling, and the tree showing signs of decline, the damage most likely occurred during the spring of 1988. Spring is the time when this type of bear feeding behavior occurs (Glover 1955, Poelker and Hartwell 1973, Giusti and Schmidt 1988).

The discovery of a Port Orford cedar that has been fed upon expands the list of tree species susceptible to black bear damage. Given the continued controversy over black bear feeding habits in redwood forests (Giusti and Schmidt 1988), the public outcry over black bear depredation programs (Gourley and Vomocil 1987), and the limited information available regarding conifer feeding by black bears, such information should be useful to those charged with the responsibility of managing black bear populations in the Pacific Northwest.

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—Gregory A. Giusti, Farm Advisor, University of California, Cooperative Extension, 883 Lakeport Blvd., Lakeport, CA 95453. *Accepted for publication January 1990.*

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