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ASSESSING WILDLIFE–HABITAT–RELATIONSHIPS MODELS: A CASE STUDY WITH CALIFORNIA OAK WOODLANDS

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Resource managers require efficient and accurate means of assessing habitat suitability for wildlife in land-use planning (Thomas 1982). For example, assessments of habitat suitability are needed to evaluate potential environmental effects of habitat alterations on wildlife or to identify potential preservation areas on the basis of high biological diversity (Motroni et al. 1991, Scott et al. 1993).

Field surveys required to determine species using an area generally are time and labor intensive (Verner 1983). Consequently, most states have developed computerized wildlife-information systems to predict habitat occupancy and habitat associations of wildlife for different locations and vegetation types (DuBrock et al. 1981, Mead 1981, Reay 1991).

Wildlife–habitat–relationships (WHR) databases are matrices to predict the presence or relative abundance of species within particular areas or seral stages of vegetation types. More detailed predictions include habitat suitability ratings for various life requisites of species such as reproduction, feeding, and cover.

Most WHR models rely on historical information and "expert opinion" as the basis for their database. Before actual application, however, WHR models should be tested (Salwasser and Krohn 1982, Marcot et al. 1983, Hurley 1986, Verbyla and Litvaitis 1989). If a model does not perform at an acceptable level of accuracy, it should be refined and retested until it does (e.g., Marcot et al. 1983). Defining the acceptable accuracy level varies with the specific application of the model and the objectives of the manager. Hurley (1986) felt that resource managers were comfortable with accuracy levels of about 75–80% of the total model output. However, many WHR models are used for making land-use decisions before their accuracy has been assessed.

Over the past decade, state and federal resource agencies and private resource managers in California have cooperated in the development of numerous wildlife–habitat models. Early attempts were regional models such as the Wildlife Habitat Information Matrix Program (WHIMP [Marcot 1979]) for northwestern California and the Verner and Boss (1980) model for the western Sierra Nevada (SNWHR). More recently, an interagency group cooperated in developing a computerized California wildlife–habitat–relationships (CWHR) database for the entire state (Airola 1988). Preliminary tests of selected aspects of both regional and statewide models have indicated that they perform with varying degrees of accuracy. For example, Raphael and

Marcot (1986) found that 11% of the species predicted by WHIMP were not observed (commission error) and 14% of the species observed were not predicted by the model (omission error). Dedon et al. (1986) found that commission errors of SNWHR varied by vegetation type and seral stage, with relatively large numbers of commissions (range = 25–78%) noted in all types and stages examined. Similar results were shown by Avery and Van Riper (1990) in tests of the CWHR model.

With the exception of Raphael and Marcot (1986), most tests have been restricted to birds. Tests of WHR models typically are limited to measuring levels of concordance with predictions of species' presence. Evaluations of other model predictions such as habitat suitability ratings and residency status must be made before the validity of the models can be determined.

We compared predictions of the statewide CWHR (Airola 1988) and the regional SNWHR (Verner and Boss 1980) models using data collected from 3 locations representing oak (Quercus spp.) woodland vegetation types in California. Specifically, we examined predictions of presence and seasonal occurrence. We gathered data for amphibians, reptiles, birds, and small mammals at all 3 sites.

STUDY SITES

Study sites were Sierra Foothill Range Field Station (SFRFS), Yuba County; San Joaquin Experimental Range (SJER), Madera County; and Tejon Ranch (TR), Kern County. These study sites ranged from 1,700–8,000 ha. All study sites contained primarily oak woodlands, although the type and arrangement of oaks differed among areas. Blue oak (Quercus douglasii), interior live oak (Q. wislizenii), and gray pine (*Pinus* sabiniana) dominated SFRFS, with California black oak (*Q.* kelloggii), valley oak (*Q. lobata*), California buckeye (Aesculus *californica*), and ponderosa pine (*Pinus* ponderosa) also present. Blue oak, interior live oak, and gray pine dominated SJER, and TR was dominated by blue oak but also contained major stands of valley oak, interior live oak, canyon live oak (*Q.* chrys*olepis*), California black oak, and Brewer's oak (Q. garryana var. breweri). More detailed descriptions of the study sites are found in Block (1989).

METHODS

Most data were from a study (Block et al. 1988, Block 1989, Block and Morrison 1991) that included all 3 study sites. Additional data were from a long-term bird-population monitoring study at SJER (Verner 1987, Verner and Milne 1989).

Data from each study site were tested separately against predictions of the CWHR model (Airola 1988). Information used to construct the database came from literature and expert opinion and included basic habitat requirements and distributions of vertebrates (Ziener et al. 1988, 1990*a*,*b*). The model is partitioned by major habitat types and various seral stages (habitat stages) within each type (Mayer and Laudenslayer 1988). Distribution and habitat information for each species were used to predict presence, residency status, and habitat suitability within restricted geographic areas (e.g., counties, latitude–longitude blocks [latilongs], jurisdictional units).

Additional tests using the avian data sets from SJER and SFRFS were done for the SNWHR model of Verner and Boss (1980). The format of SNWHR is similar to the CWHR, except that it is a regional model applicable only to habitats along the western slope of the Sierra Nevada, California.

Field Methods

Amphibians and Reptiles.—We used pitfall traps to determine presence of amphibian and reptile species. Pitfall traps consisted of 3.8-L plastic buckets covered with plywood elevated 5–10 cm above the lip of the bucket. Traps were arrayed in 6 × 6 grids with 20-m between traps. We placed 13 grids at TR and 4 each at SJER and SFRFS for a total of 740 traps (16 traps destroyed by cattle were excluded from the analysis). We rotated the order in which we opened grids to account for spatial and temporal variations in environmental conditions and animal activity (Block et al. 1988). Traps were monitored during fall, winter, and spring, 1987–1989 for a total of 98,592 trap days. Traps were examined every 2–4 days. Captures were identified and removed from the trapping grid.

We measured habitat characteristics within a 5-m radius of each pitfall station. Information from all stations was combined to characterize habitat for the entire grid. Cover of woody vegetation by species was recorded for 4 height intervals (0–1 m, >1–2 m, >2–5 m, >5 m) at 10 point intercepts at 1-m intervals along a random bearing bisecting the center of the plot. We measured the heights of ≤5 trees using a clinometer. When >5 trees were present within the plot, we measured the tree nearest the 2-, 4-, 6-, 8-, and 10-m point intercepts. More detailed descriptions of the methods used may be found in Block and Morrison (1991).

Birds.—Bird species' presence was sampled using a point-count procedure (Reynolds et al. 1980, Verner 1985). Observers recorded all birds detected by sight or sound within a 100-m radius for 5 minutes. Five highly skilled and trained observers conducted point counts. All observers spent at least 1 month learning bird vocalizations and behavior patterns prior to conducting counts. Effort was distributed among observers to ensure that each counting station was sampled by ≥2 individuals during a given season to minimize biases for detecting and correctly identifying species (Verner 1987). We established 100–103 counting stations at each study area. We omitted counting stations from our analyses (described below) which did not correspond to a CWHR or SNWHR habitat stage. Points were spaced 300–400 m apart to minimize the probability of recording the same individual at adjacent points. Each point was sampled 3 times each breeding season (Mar–May) and 5 times each nonbreeding season (Oct–Jan). Counts were conducted during 3 breeding (1986–1988) and 2 nonbreeding (1986–1987 and 1987–1988) seasons at TR and 2 breeding (1987–1988) and 1 nonbreeding (1987–1988) season at both SJER and SFRFS. More detailed descriptions of the methods used are given in Block (1989).

Habitat characteristics were measured at three 0.14-ha circular plots (20-m radius) randomly placed within the 100-m radius of each counting station. Tree diameters were measured with a Biltmore stick and heights with a clinometer. The horizontal width of all tree crowns was measured in 2 perpendicular directions, and these measures were applied to the generalized ellipse equation (Selby 1970:13) to estimate canopy cover.

Small Mammals.—Small mammal species were sampled using the amphibian and reptile pitfall traps and Sherman live traps (H. B. Sherman, P.O. Box 20267, Tallahassee, FL 32316). Traps were arrayed in 8 × 8 grids with 15-m between traps. Twelve grids were established at TR and 4 each at SJER and SFRFS. We trapped small mammals throughout 1988–1990, accumulating 21,392 nights of trap effort (8,996 at TR, 8,758 at SJER, and 3,638 at SFRFS). Captured animals were identified, aged, measured, marked, and released. Habitat characteristics were measured at all pitfall and live-trap stations ($n = 1,280$) using the methods described above for amphibian and reptile habitat. Data from all trapping stations in each grid were pooled to provide a single sample.

Data Analysis

Data from all 3 study sites were compared to the WHR models for predictions of species' presence; only the avian data were compared with predictions of residency status. We input the following information to CWHR to generate predictions: habitat type and stage, study area location by latilong, a list of elements to exclude, and taxonomic group. We excluded only elements with no chance of occurring at a site (e.g., tidal pools, wharfs, jetty, kelp). By including most elements, the species lists provided by CWHR included many species not likely to occur in the area (i.e., commission errors) but minimized omission of species. We retrieved data for the SNWHR model from the matrices provided by Verner et al. (1980:79–92).

Data from each of the 3 areas were compared to CWHR separately; because SJER and SFRFS were the only study sites in the western Sierra Nevada, only data from SJER and SFRFS were used to test the SNWHR model. All tests of the SNWHR model were restricted to bird species predictions.

Because our field methods for birds were biased towards detecting terrestrial species (primarily passerines), we considered only these species in our comparisons. Nocturnal species (e.g., owls and nightjars), diurnal raptors, and waterbirds were excluded from our analyses. We evaluated all commissions to determine if our failure to detect them could be explained by the absence of special habitat elements.

Avian Data Sets.—We calculated the quadratic mean for tree diameters (Mayer and Laudenslayer 1988:12) using the equation given by Husch et al. (1982:23). The quadratic mean for tree diameter and percent tree canopy cover were used in a cluster analysis to group census points into habitat types and stages defined by the CWHR model (Mayer and Laudenslayer 1988). Mean tree height and percent canopy cover were used in cluster analyses to classify census points to habitat types and stages defined by the SNWHR model (Verner and Boss 1980). We used an unweighted pair-group method (UPGMA) of cluster analysis based on the Euclidean distance between observations (Pielou 1984:13–82).

We compared lists of species predicted by the models with those found during bird counts to determine concordance and discordance. We compared the residency status given by the model for detected species with our observations (Block 1989:31–42) by noting whether the empirical data matched the predictions of the models.

Sampling *Effort* and Temporal Considerations.—To determine the sampling effort needed to evaluate WHR models, we used a bootstrap technique (Efron 1982:29–36) to estimate the number of counting stations needed to detect all species present. We subsampled with replacement the number of species detected at counting stations at 1-station increments. Two-hundred and fifty subsamples were taken for each increment. We used the set of means for each increment in a nonlinear regression (Draper and Smith 1981:458–517) to estimate the asymptote, hence the number of counting stations required to account for most species present.

We used Verner's data set (Verner 1987) consisting of point counts done at SJER during the breeding seasons of 1985–1990 to evaluate the number of years an area should be surveyed to determine the species present. Two hundred and ten counting stations were sampled by 3–7 observers recording all birds seen or heard during a 5-minute period at each counting station. We evaluated the number of years needed to detect the maximum number of species by calculating the mean number of birds detected for each yearly increment.

Small Mammals and Herpetofatma.—We classified each pitfall and live-trap grid to the appropriate WHR

Table 1. Characteristics of California wildlife-habitat-relationships (CWHR) habitat classes at 3 study areas in California: San Joaquin Experimental Range, Madera County; Tejon Ranch, Kern County; and Sierra Foothill Range Field Station, Yuba County, 1986–1988.

Variable	San Joaquin Experimental Range			Tejon Ranch				Sierra Foothill Range Field Station				
	VC-3S[a]	VC-3P	VC-3M	VH-4P	VH-5P	MH-3D	MH-4D	VC-3S	VC-3P	VC-3M	VC-3D	VC-4S
Number of bird counting stations	76	11	16	67	11	12	6	17	48	14	13	7
Tree canopy cover (%)[b]	18.5 (0.9)	29.6 (1.5)	45.3 (2.2)	32.4 (1.4)	33.0 (3.4)	60.5 (4.5)	68.4 (6.0)	15.7 (2.0)	31.3 (1.0)	52.0 (2.1)	67.1 (3.4)	20.9 (3.3)
Tree dbh (cm)[c]	25.3 (1.0)	27.3 (2.2)	20.1 (1.1)	31.4 (1.3)	66.6 (6.2)	25.5 (2.6)	38.2 (2.2)	25.7 (1.4)	24.5 (0.7)	24.6 (1.8)	21.3 (1.2)	43.9 (4.4)
Frequency[d]												
Blue oak	65	11	15	64	5	4	4	17	48	14	13	6
Interior live oak	64	10	16	17	3	5	1	14	45	14	13	6
Gray pine	33	10	14					8	35	13	11	5
Valley oak				32	11	2	5	1	9	2	4	2
California black oak	3			12	4	6	6					
Canyon live oak				11	2	12	5					

[a] VC = Valley–Foothill Hardwood–Conifer; VH = Valley Foothill Hardwood; MH = Montane Hardwood; 3 = pole tree; 4 = small tree; 5 = medium–large tree; S = sparse; P = open; M = moderate; D = dense cover.
[b] Mean (standard error).
[c] Quadratic mean (standard error).
[d] Number of counting stations where it occurred.

habitat according to cover of overstory trees (>5 m). For small mammals, data were pooled from pitfall and live traps to help negate the bias each has for catching different species (Szaro et al. 1988, Block and Morrison 1990). We used captures in pitfall traps for analyses of amphibians and reptiles. Capture data were used only to indicate presence of amphibian, reptile, and small mammal species. We compared the lists of species detected during our trapping efforts with species from the CWHR model to determine omission, commission, and equivalence. Snakes were excluded from all comparisons because they are not sampled adequately by pitfall traps.

RESULTS

Avian Analyses

CWHR Habitat Classes Sampled.—Three CWHR habitat classes at SJER, 5 at SFRFS, and 4 at TR were sampled by bird counting stations (Table 1). The 3 classes at SJER were all stages of Valley–Foothill Hardwood–Conifer (VC) habitat representing different amounts of canopy closure for pole-sized trees. Habitat stage VC-3S (pole-sized trees, 15–28 cm dbh and sparse canopy cover, 10–24%) was most prevalent at SJER. Similarly, habitat types at SFRFS represented different stages of the VC type. The most prevalent habitat class at SFRFS was VC-3P (pole-sized trees with open [25–39%] canopy cover). Stages of 2 major types, Valley Foothill Hardwood (VH) and Montane Hardwood (MH), were represented at TR. Two stages of VH were present representing open stands of different-sized trees (small [29–60 cm dbh] and medium to large [>61 cm dbh]), and 2 classes of dense (60–100%) MH were present, 1 with pole-sized trees and the other with small trees. Habitat stage VH-4P (small trees with open cover) dominated TR.

SNWHR Habitat Classes Sampled.—The cluster analyses classified 1 habitat stage of gray pine–oak woodland (GPO-3A) at SJER and 2 habitat stages gray pine–oak woodland (GPO-3A and GPO-3B) at SFRFS (Table 2). Habitat class GPO-3A included pole-medium sized trees from 6.1–15 m tall providing from 0–39% canopy cover. Habitat class GPO-3B also included

Table 2. Characteristics of habitat stages of the Sierra Nevada wildlife–habitat–relationships (SNWHR) model (Verner and Boss 1980) tested at 2 study areas in California, 1986–1988.

	San Joaquin	Sierra Foothill	
Variable	GPO-3A[a]	GPO-3A	GPO-3B
Number of bird counting stations	**102**	**60**	**41**
Tree height[b] (m)	**10.2 (0.3)**	**8.0 (0.2)**	**8.5 (0.1)**
Tree canopy cover[b] (%)	**22.5 (1.2)**	**24.3 (1.3)**	**49.0 (1.7)**
Frequency[c]			
Blue oak	**89**	**59**	**41**
Interior live oak	**89**	**54**	**39**
California black oak	**0**	**7**	**11**
Gray pine	**56**	**39**	**35**

[a] GPO = Gray pine–oak habitat.
[b] Mean (standard error).
[c] Number of counting stations where it occurred.

pole-medium sized trees providing from **40–69%** canopy cover.

Sampling *Effort* and Temporal Considerations.—The functions derived by bootstrapping approached asymptotes between **52** and **94** species (Table **3).** The asymptote for TR during the breeding season was approached at about **72** species, which was achieved after sampling **50** counting stations (Fig. 1A). For the nonbreeding season, the asymptote was approached at about **52** species, or **51** counting stations (Fig. 1A). At SJER, the asymptote was approached with **84** species and **56** stations for breeding and **61** species and **55** stations for the nonbreeding season (Fig. 1B). At SFRFS, the bootstrap curve approached the asymptote with approximately **94** species and **51** counting stations for breeding and **52** species and **50** counting stations during the nonbreeding season (Fig. 1C). The distribution of residuals (Fig. 1) indicated that the functions derived by bootstrapping overestimated the number of species, hence the number of counting stations. Thus, our results are conservative because they may actually overestimate the number of counting stations needed for an adequate sample. The curve of the length of time needed to record all species did not appear to approach asymptote at ≤ 6 years of sampling (Fig. **2).**

These results suggest that the spatial extent of our sampling efforts was adequate for 3 of the **12** CWHR habitat stages surveyed and 2 of the **3** SNWHR stages sampled. Estimates of commission and omission errors for the stages sampled inadequately may be biased, with commissions being overestimated and omissions underestimated. Consequently, we reported only errors of omission for these stages recognizing that these probably represent only a proportion of the total number of such errors. Commissions were reported only for stages sampled by enough counting stations.

Avian Analyses Using *CWHR.*—From **46–71%** of the species predicted by the model were detected during field surveys, averaging **61.4%** (n = **12,** SE = **1.7)** for breeding and **57.7%** (n = **12,** SE = **2.1)** for nonbreeding seasons (Table

Table 3. Number of bird species detected at the asymptotes of functions resulting from nonlinear regression analyses of bootstrap means.

Study area Season	Mean number of species	Confidence limits Lower	 Upper
Tejon Ranch			
Breeding	**72.2**	**71.2**	**73.2**
Nonbreeding	**51.6**	**50.9**	**52.2**
San Joaquin			
Breeding	**83.7**	**82.5**	**84.8**
Nonbreeding	**61.2**	**60.1**	**62.2**
Sierra Foothill			
Breeding	**93.8**	**92.5**	**95.2**
Nonbreeding	**52.4**	**51.6**	**53.2**

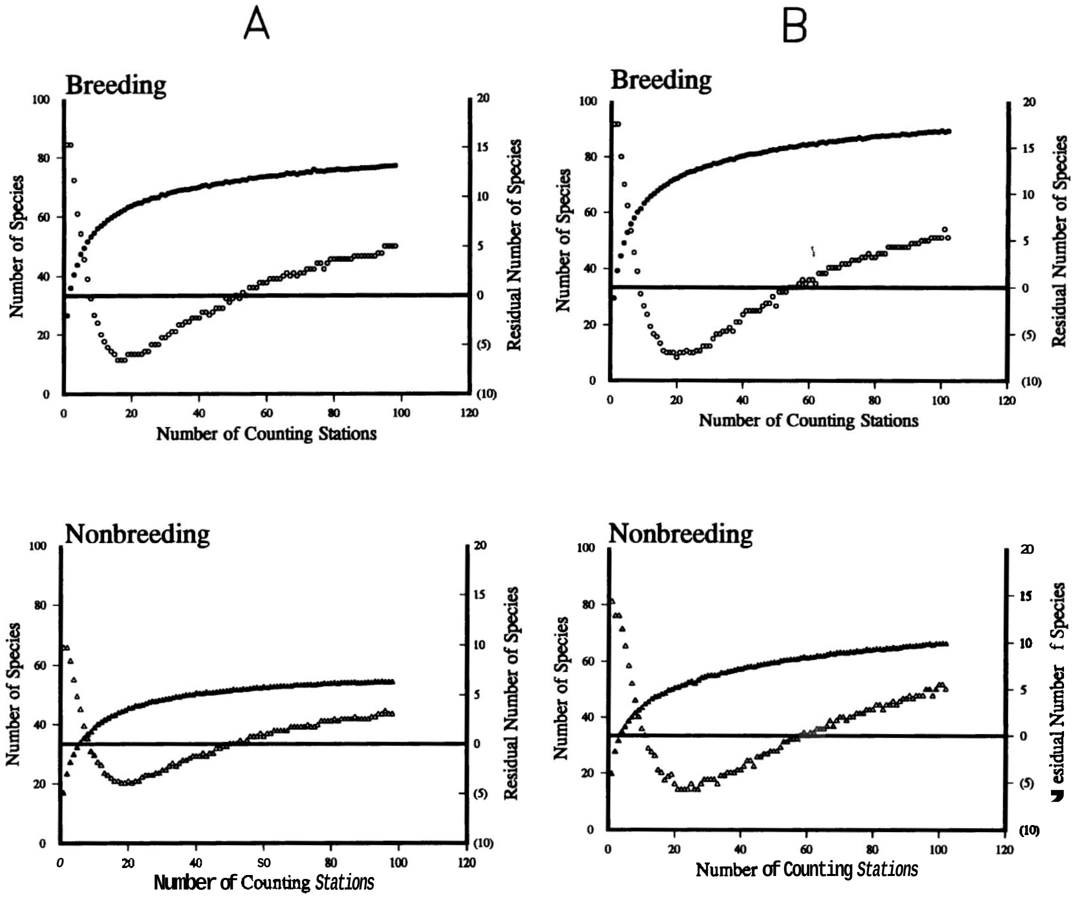

Fig. 1. Bootstrap analyses of the number of species detected (solid markers) showing the distribution of residuals (open markers) with increasing sampling effort of counting stations during breeding and nonbreeding seasons, 1986–1988, at (A) Tejon Ranch, Kern County; (B) San Joaquin Experimental Range, Madera County; and (C) Sierra Foothill Range Field Station, Yuba County, California.

4). The CWHR model correctly predicted the residency status of **4856%** of the species.

Commission errors ranged from **29–44%** of the species predicted for the **3** common habitat stages, averaging **33.3%** (n = **3,** SE = **5.0**) during breeding and **23.0%** (n = **3,** SE = **0.3)** during nonbreeding seasons (Table 4). Most commission errors were of species predicted to occupy habitats of high suitability, averaging **52.3%** (n = **3,** SE = **1.5)** of **all** commissions recorded during the breeding season and **62.3%** (n = **3,** SE = **0.3)** during the nonbreeding season.

Omission errors ranged from **6–39%** of all species detected, averaging **19.2%** (n = **12,** SE = **3.2)** during breeding and **19.8%** (n = **12,** SE = **2.9)** during nonbreeding seasons (Table 4). Curiously, the highest number of omissions were recorded for habitat stages sampled by limited number of counting stations, such as the MH stages at TR, VC-3M at SJER, and VC-3M and VC-3D at SFRFS (Table **4).**

Avian Analyses ***Using SNWHR.*****—From 62–80%** of the species predicted by SNWHR were recorded in the held, averaging **76.0%** (n = **3,** SE = **2.1)** during breeding and **67.3%** (n = **3,**

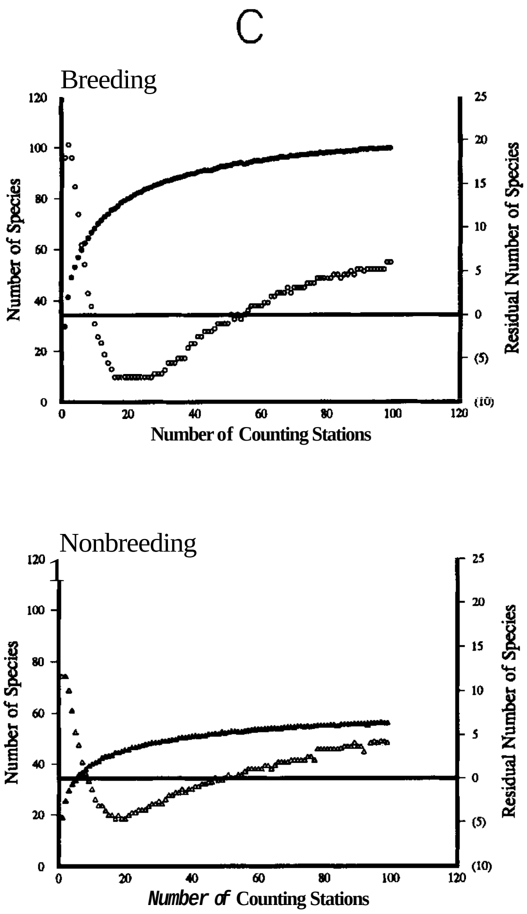

Fig. 1. Continued.

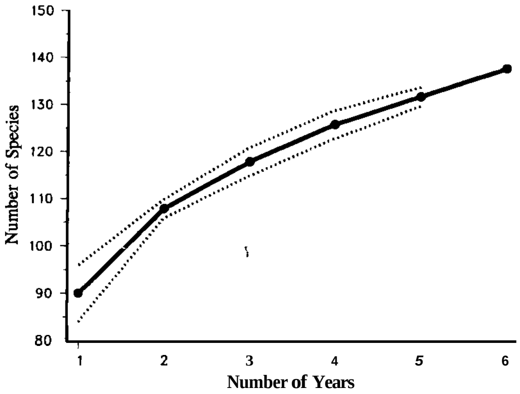

Fig. 2. Number of species detected (mean is solid line, standard error is dotted line) with increasing years of sampling effort at San Joaquin Experimental Range, Madera County, California, 1985–1990.

SE = 3.0) during nonbreeding seasons (Table 5). The SNWHR model correctly predicted the residency status of 61–78% of the species.

Commission errors averaged 22.5% (n = 2, SE = 2.5) for the breeding season and 33.3% (n = 2, SE = 2.4) for the nonbreeding season (Table 5). Over one-half of all commission errors were species predicted to occur in suitable habitat, averaging 51.5% (n = 2, SE = 3.5) for the breeding and 51.5% (n = 2, SE = 1.5) for the nonbreeding season. An average of 18.0% (n = 3, SE = 4.6) of the species were omitted from model predictions for the breeding season and 16.3% (n = 3, SE = 1.2) for the nonbreeding season (Table 5).

Amphibians, Reptiles, and Small Mammals

Pitfall and livetrap grids at SJER sampled 3 CWHR habitat classes (VC-3S, VC-3P, and VC-3M), 3 at SFRFS (VC-3P, VC-3M, and VC-3D), and 9 at TR (VH-3S, VH-3P, VH-4P, VH-4M, VH-5S, MH-3P, MH-3M, MH-4S, and MH-4D).

An average of 14.8% (n = 12, SE = 1.0) of the amphibian species predicted for each habitat stage were captured (Table 6). Eight omitted amphibian species were found in the 12 habitat stages sampled. About 41% (n = 12, SE = 4.8) of the predicted reptiles were captured with 4 omitted species recorded. An average of 32.3% (n = 15, SE = 3.3) of the small mammals predicted by the models were captured in the pitfall or live traps; 14 omitted species were recorded among the 15 habitat stages sampled.

DISCUSSION

Our results call into question the accuracy of WHR-type databases in California. Whether these results extend to wildlife–habitat mod-

Table 4. Comparison between California wildlife–habitat–relationships (CWHR) predictions and field data of bird species occurrence at 3 study sites for breeding (B) and nonbreeding (N) seasons, 1986–1988.

Habitat type	Stage[d]	Location[e]	No, species predicted		% found[a]		% mmmission[b]		% omission[c]	
			B	N	B	N	B	N	B	N
Valley–Foothill Hardwood-Conifer	3S	SJER	97	65	56	57	44	42	10	12
	3s	SFRFS	96	69	60	53			14	10
	3P	SJER	94	63	70	67			12	10
	3P	SFRFS	94	65	69	67	31	32	16	14
	3M	SJER	82	56	61	56			24	23
	3M	SFRFS	78	60	64	59			21	26
	3D	SFRFS	66	45	58	57			38	31
	4s	SFRFS	93	67	54	46			16	14
Valley–Foothill Hardwood	4P	TR	89	60	71	70	30	29	6	16
	5P	TR	89	59	55	51			6	9
Montane Hardwood	3D	TR	58	37	64	60			36	39
	4D	TR	57	37	56	49			31	33

[a] (No. species found that were predicted/no. species predicted) × 100.
[b] (No. species not found but predicted/no. species predicted) x 100.
[c] (No. species omitted/no. species found) x 100.
[d] 3 = pole tree (15–28 cm); 4 = small tree (29–60 cm); 5 = medium–large tree (>61 cm); S = sparse (10–24%); P = open (25–39%); M = moderate (40–59%); D = dense (60–100%).
[e] SJER = San Joaquin Experimental Range; SFRFS = Sierra Foothill Range Field Station; TR = Tejon Ranch.

els of other states is unknown and cannot be evaluated until those models are validated. Our results and those of similar tests done elsewhere (e.g., Timothy and Stauffer 1991), however, clearly demonstrate the need to test all WHR databases.

Our analyses were done at different levels to evaluate different aspects of the models' predictions. The most basic comparisons were to evaluate whether predictions of species' occurrence matched our field observations. Three results were possible: species predicted were detected; species detected were not predicted; or species predicted were not detected. The first possibility represents an accurate prediction; the second possibility is an inaccurate prediction. The failure to detect species predicted by a model, the third possibility, may or may not be attributed to inaccurate predictions of the model (Dedon et al. 1986). Such instances may indicate insufficient sampling to locate all species present. Insufficient sampling can result from using inappropriate methods or by not sampling long enough or over a large enough area to detect all species present.

Our bootstrap analyses indicated that surveys need to be conducted for >5 years and include >50 counting stations to minimize

Table 5. Comparison of predictions by Sierra Nevada wildlife–habitat–relationships (SNWHR) and field records of bird species occurrence in gray pine–oak habitat at 2 study sites for breeding (B) and nonbreeding (N) seasons, 1986–1988.

Habitat stage[d]	Location[e]	No. species predicted		% found[a]		% commission[b]		% omission[c]	
		B	N	B	N	B	N	B	N
3A	SJER	91	63	75	68	25	32	14	17
3A	SFRFS	92	62	80	72	20	28	13	18
3B	SFRFS	74	63	73	62			27	14

[a] (No, species found and predicted/no. species predicted) x 100.
[b] (No species not found but predicted/no. species predicted) x 100.
[c] (No. species omitted/no. species found) × 100.
[d] 3 = trees 6.1–15 m tall; A = 0–39% canopy cover; B = 40–69% canopy cover.
[e] SJER = San Joaquin Experimental Range, SFRFS = Sierra Foothill Range Field Station.

Table 6. Comparison of predictions of California wildlife–habitat–relationships (CWHR) with actual field data for amphibians, reptiles (excluding snakes), and small mammals at 3 oak woodland sites in California from spring–fall, 1986–1988.

				Amphibians[a]				Reptiles				Small mammals			
Habitat type	Stage[b]	Location[c]	N[d]	P	F	C	O	P	F	C	O	P	F	C	O
Valley–Foothill Hardwood-Conifer	3S	SJER	2P, 1L	10	1	9	1	9	3	6	0	9	2	7	1
	3P	SJER	2P, 1L	10	1	9	1	6	3	3	1	8	2	6	2
	3P	SFRFS	1P, 1L	8	1	7	0	6	3	3	0	7	3	4	2
	3M	SJER	2L									10	4	6	1
	3M	SFRFS	1P, 2L	9	2	7	0	6	3	3	1	6	2	4	2
	3D	SFRFS	2P, 1L	9	1	8	1	5	3	2	0	7	2	5	2
Valley–Foothill Hardwood	3S	TR	2L									12	3	9	1
	3P	TR	2L									12	3	9	1
	4P	TR	2P	12	0	12	0	8	1	7	0	14	7	7	0
	4M	TR	1P	10	1	9	0	8	1	7	0	8	4	4	0
	5S	TR	3P, 2L	12	2	10	0	9	4	5	0	10	1	9	2
Montane Hardwood	3P	TR	1P, 2L	5	1	4	0	4	1	3	0	8	3	5	0
	3M	TR	1P, 1L	5	1	4	0	3	1	2	0	7	1	6	0
	4S	TR	1P, 2L	5	1	4	0	4	2	2	0	8	4	4	1
	4D	TR	4P, 1L	4	1	3	3	5	3	2	0	3	1	2	1

[a] P = number of species predicted by CWHR; F = number of predicted species found; C = number of predicted species not detected; O = number of species found that were omitted from CWHR predictions.
[b] 3 = pole tree (15–28 cm); 4 = small tree (29–60 cm); 5 = medium–large tree (>61 cm). S = sparse cover (10–24%); P = open (25-39%); M = moderate (40–59%); D = dense (>60%).
[c] SJER = San Joaquin Experimental Range, SFRFS = Sierra Foothill Range Field Station; TR = Tejon Ranch
[d] P = number of pitfall grids, L = number of livetrap grids.

species not detected. Consequently, we may not have sampled long enough for all habitat stages and the spatial extent of our efforts may have been adequate for only 3 CWHR habitat stages (VC-3S at SJER, VC-3P at SFRFS, and VH-4P at TR) and 2 SNWHR stages (GPO-3A at SJER and GPO-3A at SFRFS). Thus, we restricted our analyses of commissions to only these 5 stages. Further, the size of each of our study sites may not have sampled all of the variation in habitat within each latilong, potentially leading to greater numbers of commission errors. We excluded few habitat elements when we generated species lists from CWHR. By excluding few elements, lists included far more species than actually occurred at a site, resulting in greater commissions. The trade-off, however, was that as more species were committed, less were omitted, and vice versa. The large numbers of commission errors that we found were not unique to this study. Dedon et al. (1986), Hejl and Verner (1988), and Avery and Van Riper (1990) also noted that many species listed by the models were not found during field surveys. Dedon et al. (1986) concluded that extensive commission errors were by design of the model developers to include all species that had even a slight chance of occurring. Avery and Van Riper (1990) suggested that errors of commission were to be expected given the varied sources from which the WHR databases were constructed. Thus, commissions are probably not fatal flaws in the models.

Avery and Van Riper (1990) considered errors of omission to be far more serious than errors of commission. They found numerous species omitted from CWHR, even though their sampling efforts were less extensive than ours (i.e., sampled fewer points, limited to 1 study area). We also found a substantial number of species omitted from predictions of both models. Some species were omitted entirely, whereas others were omitted from a specific habitat stage or from a season where the animal occurred. The CWHR model was particularly poor in predicting the occurrence of many finch species within montane hardwood habitats at TR. Similarly, Avery and Van Riper (1990) in oak woodlands and Hejl and Verner (1988) in Shasta red fir (*Abies magnifica*) forests found that numerous finches were omitted from predictions of CWHR.

Residency Status

The models failed to predict the residency status of 32–52% of the species within any habitat stage. Many errors (n = 302) were attributable to omitted species. We recorded a number of instances (n = 155) when we found species during only 1 season (breeding or nonbreeding) that were predicted to occur year-round. Some of these cases may represent species that were present but not detected during our surveys. Species that occurred year-round but were predicted to occur only during 1 season, however, represent definite errors in predictions of residency status. Similar conclusions were reported by Avery and Van Riper (1990). Many such errors in residency are easily corrected in the databases.

CWHR versus SNWHR

The SNWHR model seemed more accurate than the CWHR model when comparing results from SJER and SFRFS, areas where both models were tested. We found fewer errors of omission for SNWHR than for CWHR (Tables 4 and 5). Further, fewer commissions were recorded for the SNWHR model compared to the CWHR model (Tables 4 and 5). The difference in model performance is possibly because CWHR is a statewide database and SNWHR is restricted to the western slope of the Sierra Nevada. Thus, CWHR develops a model for a species within each habitat type for the entire state and adjusts species lists according to the known geographic range of the species. SNWHR develops habitat-specific models applicable to a smaller geographic area. Many differences in accuracy between the models may be attributed to the differences in the geographic scales at which the models were developed.

MANAGEMENT IMPLICATIONS

The primary use of WHR models in California is to provide lists of species that might be found at a particular location. The lists provided contained species that were not detected and failed to include many species that did occur (302 cases of omitted species). An argument can be made that high rates of commission errors prevent critical errors of omission from being made. Unfortunately, omissions still occur as noted by us and other evaluations of these models (e.g., Dedon et al. 1986, Raphael and Marcot 1986, Hejl and Verner 1988, Avery and Van Riper 1990, Timothy and Stauffer 1991).

Certainly a major problem underlying inaccuracies of WHR models is the scale of observation. Even regional models such as WHIMP or SNWHR encompass large geographic areas containing many variations in vegetation types, seral stages, and local conditions. Expectations of these models to predict habitat occupancy and suitability accurately in specific locations are perhaps unreasonable. Likely, accuracy of models will improve if they are developed for smaller geographic areas. Models must continually undergo validation through tests such as ours. Overall model performance should improve as it is validated and revised.

We recognize the need for computerized databases for rapid retrieval of wildlife habitat and distribution information. Information provided by a model, however, is only as good as the data from which it is derived. The data that comprise the models must be evaluated critically to identify model accuracy and detail. Species lacking adequate data should be targeted for research to obtain information needed. Until these data are incorporated into