RARE MIGRANTS IN CALIFORNIA: THE DETERMINANTS OF THEIR FREQUENCY

STEVE HAMPTON, 19-D Solano Park, Davis, California 95616

As autumn-weekend crowds of birders at Point Reyes, California, attest, the state regularly receives thousands of wayward migrating birds each year, representing over a hundred species. The vast majority of these birds are neotropical migrant passerines whose breeding ranges are in Canada and the eastern United States and whose primary migration route is east of the Rocky Mountains. While the trees at the lighthouse may be dotted with Blackpoll Warblers, the rare appearance of a Golden-winged Warbler or a Red-eyed Vireo is sure to draw much greater attention. What is it that makes some species so much more "common" than others? What characteristics of each species determine the frequency of their appearances?

In this paper, I develop and evaluate a model, employing multiple regression analysis, that explains the frequency of 84 species of eastern birds in California. The model attempts to explain vagrancy as a function of various characteristics of each species' range and migration patterns as well as its population size and taxonomic classification. This analysis is limited to autumn occurrences of migrant passerines and woodpeckers from eastern North America (as opposed to species from Siberia or the American Southwest) in northern California.

The results allow conclusions to be drawn about range expansions of certain species, species birders may be missing though the birds are present, the notion of "mirror-image misorientation," and evolutionary adaptations in certain species.

A few previous studies have addressed the question of the frequency of eastern vagrants on the West Coast. These studies have relied on general observations or pairwise correlations (comparing only two variables at a time), yet some have suggested that a multiple-variable analysis would address the question more adequately.

DeBenedictis (1971: 123), focusing on vireos and warblers in California, concluded that "a large part of variation in abundance of these 'accidentals' in California can be attributed to differences in population size. The influence of other factors is minimal." These other factors include the migration distance of each species and the angle of deviation between the species' normal migration route and the route that would bring it to California.

DeSante (1973) noted that eastern species with strong easterly, rather than primarily southerly, components to their migration routes are more frequent visitors to California. From experiments with caged Blackpoll Warblers captured on the Farallon Islands, he concluded that mirror-image misorientation (which causes the birds to migrate southwest instead of southeast) is the dominant factor bringing immature warblers to California. He also noted that the majority of vagrants are immatures.

DeSante and Ainley (1980: 87) noted that "nine-primaried passerines, particularly wood warblers, are proportionally more common as vagrants on the Farallones than 10-primaried passerines with similarly sized source populations and similar breeding ranges and migration routes." These are the species currently grouped in an enlarged family Emberizidae (AOU 1983).

DeSante's (1983) analysis is the most thorough. He reasserted the importance of mirror-image misorientation but also added, "clearly, a large number of very diverse factors must be operative to cause the widely varying abundances of the many landbird species that occur on the Farallones" (p. 843). These factors include the size of the source population, the location of the species' breeding and wintering ranges, migration patterns, and whether the species is an emberizid. His analysis, however, did not consider each species individually. Instead, it grouped all the species covered into two groups ("northern" and "southeastern") and used pairwise correlations only. He concluded the discussion of vagrants by citing the need for multivariate analysis.

METHODS

Following the recommendation of the cited papers, I have developed a multivariate model in which, for each species, the number of individual birds reported during a given period of time is a function of its total population, of how far it migrates, of the westernmost longitude of its breeding range, of the distance from California to its breeding range, of whether it is an emberizid, and of whether or not it has an easterly component to its fall migration path. For each species, the model I propose can be written

$$\#BIRDS = f(POP, MIG, LONG, DIST, EMB, EAST)$$

where #BIRDS is the number of individuals reported in coastal and central northern California from July to December in the years 1989 through 1995. The Sierra Nevada, Modoc Plateau, and Owens Valley were excluded. For this data, I rely on the wealth of information collected by birders and amateurs who have reported their observations to the Northern California Rare Bird Hotline, which is managed by volunteers from the Golden Gate Audubon Society. In cases where birds on the California Bird Records Committee (CBRC) review list were reported, I have included only accepted records. For species not on the review list or whose reports have yet to be reviewed by the CBRC, I attempted to eliminate suspect reports and to avoid double-counting the same bird in a year. Possibly the same individuals returning to the same spot each year, however, are counted multiple times.

POP represents the total population size of the species. I used a coding system similar to that of DeBenedictis (1971), relying on abundance information for 62 states, provinces, or territories in the United States and Canada in the *Distributional Checklist of North American Birds* (DeSante and Pyle 1986). A score, meant to reflect actual abundance levels, was assigned to each species for each geographical area: 100 points were given for "common," 25 for "fairly common," 5 for "uncommon," and 1 for "rare." Only summer ranges were used. The resulting figures were divided by 20 when DeSante and Pyle indicated that the bird was present in only a limited portion of the territory (defined as less than 10%). The score was then multiplied by the total land area of the state or province and the scores for all areas were summed, giving an index of the total population in North America. Finally, this index was scaled so that 10 was the maximum score for the most common bird (Eastern Kingbird). Kirtland's Warbler had the lowest score with 0.0003. DeSante and Pyle made clear that their abundance codes do not refer directly to population but to the likelihood of encountering a species while birding. This has the effect of biasing POP up for conspicuous birds and down for secretive birds.

MIG refers to the distance between the species' breeding grounds and wintering grounds. This distance was calculated as the latitudinal gap between the geographical center of these ranges. The figure is given in terms of ten degrees of latitude, so that a value of 4.0 implies that there are 40 degrees latitude between the centers of the breeding and wintering ranges. The National Geographic Society (1987) guide was used for the breeding ranges, while the sixth edition of the AOU checklist (1983) was used for most of the wintering ranges.

LONG refers to a score assigned to each species to represent the westernmost longitude of its breeding range. For species breeding west of 120° W (i.e., into British Columbia or Washington state), zero points were assigned. One point was given for species nesting west to 115° W, two points for 110°W, and so on.

DIST refers to the distance from Sacramento, California, to the nearest edge of the breeding range. The figure is given in miles, divided by 100.

EMB is a dummy variable, with a value of one assigned to the emberizids (warblers, tanagers, grosbeaks, buntings, sparrows, longspurs, and icterids), and zero assigned to all other species.

EAST is also a dummy variable, distinguishing species that seem to have an easterly component to their autumn migration route. A value of one is assigned to species regularly reported from Bermuda (Ralph 1981), those that are most often seen migrating over the Atlantic Ocean (McClintock et al. 1978), and those that migrate primarily around the eastern edge of the Gulf of Mexico, rather than across it or through Texas.

Table 1 lists the complete data for each species (as well as the predicted #BIRDS from the model and the difference between the actual and the predicted total). To gain the greatest possible understanding of why a species occurs as often as it does in California, all eastern migratory woodpeckers and passerines are included (84 species), including those for which there were no reported sightings (e.g., Eastern Wood-Pewee). A 6-year period is used to minimize the effects of unusual years, as well as to include the few occurrences of species that may not show up every year. DeSante (1983) pointed out that while the number of birds may vary from year to year, the relative number of each species does not vary significantly.

The functional form of the equation above affects its modeling ability. In the 6-year period of the sample, many species were reported less than ten times, others over 200 times. Intuitively, we would like the difference between zero sightings and 40 sightings to be more significant than the difference between 200 and 240 sightings. Taking the natural logarithm of #BIRDS achieves this goal. The same logic applies to MIG, LONG, and

Table 1 Input Data and Predictions of a Model Testing Six Factors Contributing to the Occurrence of Eastern Vagrant Land Birds in California

	#BIRDS								
Species	Obs.	Pred.	Error	POP	DIST	LONG	MIG	EMB	EAST
Red-headed Woodpecker *Melanerpes erythrocephalus*	0	0	0	2.47	10	2	0.5	0	0
Yellow-bellied Sapsucker *Sphyrapicus varius*	29	6	23	2.51	12	0	3.0	0	0
Red-naped Sapsucker *S. nuchalis*	15	3	12	0.72	2	1	2.0	0	0
Eastern Wood-Pewee *Contopus virens*	0	1	-1	4.82	12	4	3.5	0	0
Yellow-bellied Flycatcher *Empidonax flaviventris*	0	6	-6	1.08	12	0	4.0	0	0
Acadian Flycatcher *E. virescens*	0	0	0	1.70	15	5	3.0	0	0
Alder Flycatcher *E. alnorum*	0	11	-11	3.53	10	0	6.0	0	0
Least Flycatcher *E. minimus*	37	8	29	5.42	8	0	3.0	0	0
Gray Flycatcher *E. wrightii*	11	5	6	0.28	2	0	1.5	0	0
Eastern Phoebe *Sayornis phoebe*	19	5	14	1.67	10	0	2.5	0	0
Great Crested Flycatcher *Myiarchus crinitus*	1	1	0	4.85	12	3	2.5	0	0
Eastern Kingbird *Tyrannus tyrannus*	25	17	8	10.00	4	0	5.0	0	0
Gray Kingbird *T. dominicensis*	0	0	0	0.13	21	7	1.0	0	0
Scissor-tailed Flycatcher *T. forficatus*	3	1	2	1.02	11	3	2.0	0	0
Blue Jay *Cyanocitta cristata*	0	1	-1	7.90	10	1	0.5	0	0
Sedge Wren *Cistothorus platensis*	1	0	1	0.44	12	3	2.0	0	0
Eastern Bluebird *Sialia sialis*	0	1	-1	2.26	10	3	1.5	0	0
Veery *Catharus fuscescens*	0	13	-13	4.59	4	0	4.5	0	0
Gray-cheeked Thrush *C. minimus*	2	9	-7	3.60	16	0	6.0	0	0
Wood Thrush *Hylocichla mustelina*	0	1	-1	3.07	13	4	2.5	0	0
Gray Catbird *Dumetella carolinensis*	7	6	1	6.25	7	0	1.5	0	0
Brown Thrasher *Toxostoma rufum*	5	1	4	4.45	9	2	1.0	0	0

(continued)

Table 1 *(continued)*

	#BIRDS								
Species	Obs.	Pred.	Error	POP	DIST	LONG	MIG	EMB	EAST
Sprague's Pipit *Anthus spragueii*	0	2	–2	0.77	9	1	2.5	0	0
Black-capped Vireo *Vireo atricapillus*	0	0	0	0.01	14	4	1.0	0	0
White-eyed Vireo *V. griseus*	1	0	1	2.10	13	4	1.5	0	0
Yellow-throated Vireo *V. flavifrons*	1	0	1	0.79	14	5	2.0	0	0
Philadelphia Vireo *V. philadelphicus*	14	3	11	0.62	10	1	3.5	0	0
Red-eyed Vireo *V. olivaceus*	36	60	–24	8.94	6	0	5.0	0	1
Blue-winged Warbler *Vermivora pinus*	3	2	1	0.18	17	6	2.5	1	0
Golden-winged Warbler *V. chrysoptera*	3	3	0	0.12	16	5	2.5	1	0
Tennessee Warbler *V. peregrina*	136	166	–30	4.80	9	0	4.5	1	1
Virginia's Warbler *V. virginiae*	21	11	10	0.74	4	1	1.5	1	0
Northern Parula *Parula americana*	22	21	1	2.32	16	5	3.0	1	1
Chestnut-sided Warbler *Dendroica pensylvanica*	124	9	115	3.33	12	3	3.5	1	0
Magnolia Warbler *D. magnolia*	91	146	–55	3.09	8	0	4.0	1	1
Cape May Warbler *D. tigrina*	17	46	–29	1.17	12	1	2.5	1	1
Black-thr. Blue Warbler *D. caerulescens*	54	15	39	0.68	16	5	2.5	1	1
Black-thr. Green Warbler *D. virens*	12	12	0	3.21	13	1	2.5	1	0
Golden-cheeked Warbler *D. chrysoparia*	0	2	–2	0.01	15	4	1.5	1	0
Blackburnian Warbler *D. fusca*	51	11	40	3.23	13	3	5.0	1	0
Yellow-throated Warbler *D. dominica*	3	2	1	1.31	15	5	1.5	1	0
Kirtland's Warbler *D. kirtlandii*	0	1	–1	0.0003	20	7	2.0	1	0
Pine Warbler *D. pinus*	1	2	–1	0.41	14	5	1.0	1	0
Prairie Warbler *D. discolor*	52	12	40	0.95	15	5	1.5	1	1
Palm Warbler *D. palmarum*	1048	87	961	0.90	12	0	3.0	1	1

(continued)

Table 1 *(continued)*

Species	#BIRDS Obs.	Pred.	Error	POP	DIST	LONG	MIG	EMB	EAST
Bay-breasted Warbler *D. castanea*	15	24	−9	0.66	12	0	4.0	1	0
Blackpoll Warbler *D. striata*	245	199	46	4.81	11	0	6.5	1	1
Cerulean Warbler *D. cerulea*	0	4	−4	0.24	15	5	4.0	1	0
Black-and-white Warbler *Mniotilta varia*	150	116	34	3.42	10	0	3.0	1	1
American Redstart *Setophaga ruticilla*	268	158	110	6.59	6	0	3.0	1	1
Prothonotary Warbler *Protonotaria citrea*	16	3	13	1.08	14	5	2.0	1	0
Worm-eating Warbler *Helmitheros vermivorus*	3	2	1	0.14	15	5	2.0	1	0
Swainson's Warbler *Limnothlypis swainsonii*	0	1	−1	0.09	15	6	1.5	1	0
Ovenbird *Seiurus aurocapillus*	40	114	−74	5.14	10	0	2.5	1	1
Northern Waterthrush *S. noveboracensis*	77	154	−77	4.07	8	0	4.0	1	1
Louisiana Waterthrush *S. motacilla*	0	3	−3	0.47	14	5	2.0	1	0
Kentucky Warbler *Oporornis formosus*	4	3	1	1.12	15	5	2.0	1	0
Connecticut Warbler *O. agilis*	23	14	9	0.25	14	1	5.0	1	0
Mourning Warbler *O. philadelphia*	20	17	3	2.59	13	1	4.5	1	0
Hooded Warbler *Wilsonia citrina*	14	3	11	1.35	15	5	2.0	1	0
Canada Warbler *W. canadensis*	10	54	−44	0.84	15	1	4.0	1	1
Scarlet Tanager *Piranga olivacea*	2	5	−3	1.51	13	5	3.5	1	0
Rose-breasted Grosbeak *Pheucticus ludovicianus*	62	32	30	4.41	11	0	3.5	1	0
Indigo Bunting *Passerina cyanea*	24	11	13	4.98	6	2	2.0	1	0
Painted Bunting *P. ciris*	0	3	−3	0.97	11	4	1.5	1	0
Dickcissel *Spiza americana*	5	5	0	2.25	11	4	2.5	1	0
Clay-colored Sparrow *Spizella pallida*	245	28	217	2.29	8	0	3.0	1	0
Brewer's Sparrow *S. breweri*	40	27	13	2.52	3	0	1.5	1	0
Field Sparrow *S. pusilla*	0	3	−3	3.03	9	3	0.5	1	0

(continued)

Table 1 *(continued)*

Species	#BIRDS Obs.	Pred.	Error	POP	DIST	LONG	MIG	EMB	EAST
Black-throated Sparrow *Amphispiza bilineata*	4	11	−7	2.10	2	1	0.5	1	0
Lark Bunting *Calamospiza melanocorys*	26	7	19	1.34	6	2	1.5	1	0
Baird's Sparrow *Ammodramus bairdii*	1	6	−5	0.22	5	2	1.5	1	0
Henslow's Sparrow *A. henslowii*	0	1	−1	0.04	13	5	1.0	1	0
Le Conte's Sparrow *A. leconteii*	2	7	−5	0.58	11	1	1.5	1	0
Sharp-tailed Sparrow *A. caudacutus*	31	8	23	0.29	12	1	2.0	1	0
Swamp Sparrow *Melospiza georgiana*	370	17	353	4.02	14	0	1.5	1	0
McCown's Longspur *Calcarius mccownii*	0	4	−4	0.32	9	2	1.0	1	0
Smith's Longspur *C. pictus*	2	17	−15	0.38	18	0	3.0	1	0
Chestnut-col. Longspur *C. ornatus*	65	7	58	1.25	7	2	1.5	1	0
Bobolink *Dolichonyx oryzivorus*	74	154	80	2.71	3	1	6.5	1	1
Eastern Meadowlark *Sturnella magna*	0	3	−3	4.71	8	4	0.5	1	0
Rusty Blackbird *Euphagus carolinus*	10	17	−7	1.44	13	0	2.0	1	0
Common Grackle *Quiscalus quiscula*	0	9	−9	8.32	9	1	0.5	1	0
Orchard Oriole *Icterus spurius*	12	6	6	2.07	10	3	2.0	1	0

DIST, where it makes sense to weight the importance of the differences among the lower values. This also requires adding 1 to #BIRDS, as the natural log of zero is negative infinity, while the natural log of one is zero. The same shifting was done for ln(LONG) and ln(MIG), so that they are really ln(#BIRDS + 1), ln(LONG + 1), and ln(MIG + 1).

Thus the final functional form for the model employs a semilog form (see Studenmund 1992) and can be written

$$\ln(\#BIRDS) = \beta_0 + \beta_1(POP) + \beta_2\ln(MIG) + \beta_3\ln(LONG) + \beta_4\ln(DIST) + \beta_5(EMB) + \beta_6(EAST)$$

Multiple regression analysis enables us to find the coefficients (the β's) that give us the best fit. The equation was solved through the use of ordinary least squares, which can incorporate both continuous and dichotomous (dummy) variables (Studenmund 1992). Moreover, the statistical significance of each coefficient can be tested. It is important to note that this analysis enables us to see the correlation of each variable with #BIRDS, independent of the other variables. That is, each coefficient captures only the effect of one variable, as if the others were held constant. The simple pairwise correlations of previous studies include cross-correlation biases that may be caused by other variables that are ignored when only two variables are considered at a time.

Once the coefficients are generated on the basis of the entire sample, the data from each species may be plugged into the model to obtain the "predicted values," the #BIRDS that the model predicts from the characteristics of that species (see Table 1).

RESULTS AND DISCUSSION

Table 2 lists the results of the regression. All of the coefficients were of the expected signs, implying that all of the variables had the expected impact in bringing these rare migrants to northern California. Most of the variables were significant at the 90% confidence level. The R^2 was 0.57, which roughly means that 57% of the variation in #BIRDS can be explained by this model. Greene (1993:154) stated, "in terms of the values one normally encounters in cross-section data [as opposed to time-series data], an R^2 of 0.50 is relatively high." Other versions of the model were run, deleting the Palm Warbler from the sample, deleting birds that winter in California from the sample, and keeping only emberizids in the sample. The results changed little, though POP and DIST did have t statistics as high as 1.50 in some versions, implying significance at low confidence levels.

Table 2 Coefficients and t Statistics Generated by Multiple Regression Using Ordinary Least Squares of a Model Testing Six Factors Contributing to the Occurrence of Eastern Vagrant Land Birds in California[a]

Variable	Coefficient	t Statistic
POP	0.03	0.36
ln(MIG)	0.80[b]	1.97
ln(LONG)	–0.87[c]	–3.48
ln(DIST)	–0.35	–1.11
EMB	1.31[c]	4.15
EAST	1.45[c]	3.49

[a] $n = 84$, $R^2 = 0.57$, $F = 17.27$

[b] Significantly different from zero, with a 95% confidence level.

[c] Significantly different from zero, with a 99.5% confidence level.

Interpretation of the coefficients is difficult because they vary with the units used for each explanatory variable and because the dependent variable (#BIRDS) is in logarithmic form. The *t* statistic, together with the confidence levels, gives the statistical likelihood that the coefficient is different from zero, that is, that the coefficient has a significant effect on #BIRDS. For example, with a sample size of 84, a *t* statistic greater than 1.66 (in absolute value) implies a 95% confidence level that the coefficient is not zero. The *t* statistics are normalized around zero, and are positive or negative depending on the sign of the corresponding coefficient. The model fits well enough that I address possible explanations for the species that seem to deviate from the model.

The Explanatory Variables

To turn first to the explanatory variables, POP is a statistically insignificant factor in determining the frequency of rare migrants, far from the dominant influence suggested by DeBenedictis (1971). The coefficient of 0.03 implies that an increase in population of 1 unit (on the scale of 0 to 10) should cause the number of sightings to increase about 8%, a level that could be unnoticed, or certainly masked by the growing number of birders that report sightings. Therefore, even with "common" rare migrants, an increase in extralimital sightings may be a poor indicator of demographic changes. Instead, weather conditions, changes in the habitat available in California, or changes in the effort or distribution of birders may be more likely explanations for short-term variations in the number of sightings. Caution must be used in interpreting this variable, however, because the data on which POP is based are relatively crude. Perhaps more exact measures of total bird populations would yield a more significant result.

Whether or not a bird migrates surely affects its frequency of extralimital records. Because nonmigratory species are excluded from the sample (and it is hard to think of a vagrant record for a nonmigratory species), MIG is undoubtedly catching the difference between those species that winter in Central or South America and those that winter in the southern U.S. The coefficient of 0.80 implies that, for every increase of ten degrees of latitude (the latitudinal spread of the state of California) the species migrates, the number of individuals reported in northern California will increase about 75%. It is no surprise that long-distance migrants get lost more than shorter-distance migrants.

LONG focuses on many eastern species' breeding ranges that extend west across Canada, some even to Alaska. Though most of these birds follow an eastern migration route that presumably evolved before the bird expanded its range west, it is not surprising that this condition leads to an increase in these species' appearances on the West Coast. The coefficient of −0.87 implies that 5.2 times more vagrants (i. e., a 520% increase) will be seen for every 10° farther west the species breeds. This variable may lend support to the concept that birds arriving in California from western Canada suffer from mirror-image misorientation (DeSante 1973). While this variable is different from EAST, it may have a similar effect. EAST refers primarily to birds already in eastern North America and whether or not they migrate over the Atlantic or across the Gulf of Mexico. However, birds in western Canada must fly southeast in autumn just to get to the eastern U.S., and thus have an easterly component to their migration regardless of how they fly farther south. If they are misoriented, they may fly southwest, hit the Pacific Coast, and perhaps hug the coast as they fly south (or head out to sea).

The distance from northern California to the breeding range (DIST) is statistically insignificant. The sample includes some non-eastern species that breed east of the target area (e. g., Brewer's Sparrow, Virginia's Warbler) and some eastern species that breed very close to it (e. g., Eastern Kingbird). If other random factors besides mirror-image misorientation, such as total "disorientation," cause a bird to lose its way, and it can get lost in any direction, we would expect some increase in sightings due merely to proximity to the bird's breeding area. DeSante (1983:843) hypothesized, "It seems likely that all mechanisms of disorientation and misorientation have been responsible, to some degree or another, for the occurrences of vagrant landbirds." My results imply that random disorientation alone is not responsible to any significant degree. The coefficient of –0.35 (which, again, is statistically not different from zero) implies that, for every 500 miles closer to California a species breeds, there should be a 48% increase in sightings.

The very high *t* statistic associated with EMB supports DeSante and Ainley's (1980) observation that the taxonomic status of the species plays an important role in determining the frequency of extralimital records. According to the coefficient of 1.31, an emberizid will be seen about 3.7 times more often than a similar bird of another family. Thus, EMB has an enormous influence and begs the question, why? DeSante and Ainley speculated that the proclivity of these species to get lost is an advanced evolutionary trait that enables these birds to adapt, to find new breeding and wintering grounds and new migration routes. Indeed, virtually all of the species that appear in numbers much larger than expected from this model (as if they were expanding their range) are emberizids.

Finally, EAST, by virtue of its strong significance, adds support to the hypothesis of mirror-image misorientation. The coefficient of 1.44 implies that species that migrate east over the Atlantic or around the Gulf of Mexico through Florida are likely to show up roughly 4.2 times more often on the West Coast than similar species that migrate straight over the Gulf or through Mexico.

Thus the coefficients suggest that both the location of the breeding range (as modeled in LONG) and the distance a species migrates (MIG) play important roles in determining the frequency of vagrancy. However, eastern birds prone to mirror-image misorientation and emberizids will stray to California many times more often than other species, regardless of other factors.

The Outliers

When a model fits well it may be useful to look at the few exceptional observations in the sample, the outliers, and to ask why they do not seem to fit as the others do.

Small deviations from the model may be explained by sampling variation in data collection, which is to be expected. Large deviations and outliers may be explained as the result of either the bird, the birders, or both. Either the species is behaving in a particularly unusual way that causes it to stray to or to avoid California or the birds are behaving as the other species in the model but birders either are finding them more easily than other species or are missing them.

The model predicts quite well for the species with less than 10 sightings, often missing by a single observation (see Table 1). The greatest deviations are for the Alder Flycatcher, Veery, and Common Grackle. The model overpredicts sightings of these birds, predicting 11, 13, and 9 respectively, when none of the three was reported [indeed, there are only two accepted California records of the Alder Flycatcher, Heindel and Patten (1996)]. While numerous and breeding west to British Columbia (at least), Alder Flycatchers, Veeries, and Common Grackles either hardly ever get lost or they reach California but birders are missing them. Birders may miss birds for two obvious reasons: their foraging habits make them difficult to see (because they are hiding, skulking, etc.), or they are difficult to identify. Criteria for identifying the Alder Flycatcher in the field during fall migration have yet to be reported. Veeries may be under-reported because of their foraging habits, identification problems, and/or actual indisposition of *Catharus* thrushes to vagrancy (the Gray-cheeked Thrush too is reported appreciably less often than expected). Common Grackles may be overlooked in a large winter flock of blackbirds. Note that a future report of a single Kirtland's Warbler or Eastern Wood-Pewee would be consistent with the model. Three other more common species that the model overpredicts are the Ovenbird, the Northern Waterthrush, and the Canada Warbler. The relative magnitudes of these overpredictions are much smaller, but a possible answer is that birders are missing them because of these species' foraging habits.

The only other species that are somewhat overpredicted are the Red-eyed Vireo, of which 60 are predicted but only 36 were reported, and the Bobolink, of which 154 are predicted but only 74 were reported. I can suggest no obvious explanations for these anomalies.

Among species greatly underpredicted by the model, three stand out as strikingly different from the others: the Palm Warbler (87 predicted and 1048 reported), the Swamp Sparrow (17 predicted and 370 reported), and, to a lesser extent, the Clay-colored Sparrow (28 predicted and 245 reported). These results suggest that these species should not be considered "out of range" in California. Rather, Palm Warblers and Clay-colored Sparrows appear to have established a new migration corridor and Swamp Sparrows a new wintering ground. If so, sightings of these species may continue to increase. The White-throated Sparrow (*Zonotrichia albicollis*) was not included in the sample because it is a well-established winter visitor in northern California (so much so that many are not reported to the Rare Bird Hotline). The results of this model indicate that the Swamp Sparrow is following a similar path.

Note that the high numbers of American Redstarts, Blackpoll Warblers, Black-and-white Warblers, and Tennessee Warblers are explained by the model. This agreement implies that these species are showing up in the numbers expected for a vagrant, have not established migration routes or wintering ranges in northern California, and show no signs of expanding their migration routes. Four other species of warblers, however, are reported far more often than the model predicts: the Chestnut-sided, Black-throated Blue, Blackburnian, and Prairie. These species may follow in the path of the Palm Warbler.

Finally, the Least Flycatcher, both sapsuckers, and the Chestnut-collared Longspur are sighted far more often in northern California than predicted. For the Least Flycatcher, this may be due to recent range expansion in Washington state. The latter three species winter in the area, providing birders with more time to find them.

The results of this analysis may be tested further with the wealth of data collected on Southeast Farallon Island. Similar models may be applicable to shorebirds, pelagic species, Alaskan and Siberian species, and species of the American Southwest. All of these groups, however, involve much smaller sample sizes with less variation, reducing the strength of interpretation of the results. Studies of larger samples, such of as the vagrancy patterns of western passerines on the East Coast or North American species in Europe, may offer better parallels.

SUMMARY

On the basis of 6 years of reported hotline sightings of vagrant eastern landbirds in northern California and multiple-regression analysis using ordinary least squares, I devised and evaluated a model testing and quantifying six factors contributing to the occurrence of these species on the West Coast: relative abundance, migration distance, western limit of breeding range, distance of breeding range from California, migration route, and membership in the family Emberizidae. The results suggest that there is a quantifiable pattern to the frequency of most eastern vagrants in California. Migration direction, location of breeding range, and taxonomic status of a species each play a significant role in determining the probability of vagrancy. On the other hand, population size may not be an important factor. By quantifying these roles, the model supports the concept of mirror-image misorientation. The model also suggests range expansions by the Palm Warbler, the Swamp Sparrow, and possibly a few other species. It suggests that some species difficult to identify, such as the Alder Flycatcher and Veery, are being missed by birders.

ACKNOWLEDGMENTS

I am very grateful to Joseph Morlan for recording the data from the northern California rare-bird alert and for providing me access to it. Any mistakes in calculating #BIRDS are purely mine. I also thank John Kemper, Alvaro Jaramillo, Philip Unitt, David DeSante, and Scott Terrill for their encouraging and helpful comments on earlier drafts.

LITERATURE CITED

American Ornithologists' Union. 1983. Checklist of North American Birds, 6th ed. American Ornithol. Union, Washington, D.C.

DeBenedictis, P. 1971. Wood warblers and vireos in California: The nature of the accidental. Calif. Birds 2:109–127.

DeSante, D. F. 1983. Annual variability in the abundance of migrant landbirds on Southeast Farallon Island, California. Auk 100:826–852.

DeSante, D. F. 1973. An analysis of the fall occurrences and nocturnal orientations of vagrant wood warblers (Parulidae) in California. Ph.D. dissertation, Stanford Univ., Stanford, CA.

DeSante, D. F., and Ainley, D. G. 1980. The Avifauna of the South Farallon Islands, California. Studies Avian Biol. 4.

DeSante, D. F., and Pyle, P. 1986. Distributional Checklist of North American Birds. Artemisia Press, Lee Vining, CA.

Greene, W. H. 1993. Econometric Analysis, 2nd ed. Macmillan, New York.

Heindel, M. T., and Patten, M. A. 1996. Eighteenth report of the California Bird Records Committee: 1992 records. W. Birds 27:1–29.

McClintock, C. P., Williams, T. C., and Teal, J. M. 1978. Autumnal bird migration observed from ships in the western Atlantic Ocean. Bird-Banding 49:262–277.

National Geographic Society. 1983. Field Guide to North American Birds, 2nd ed. Natl. Geogr. Soc., Washington, D.C.

Ralph, C. J. 1981. Age ratios and their possible use in determining autumn routes of passerine migrants. Wilson Bulletin 93:164–188.

Roberson, D. 1980. Rare Birds of the West Coast. Woodcock Publ., Pacific Grove, CA.

Studenmund, A. H. 1992. Using Econometrics: A Practical Guide, 2nd ed. Harper Collins, New York.

Accepted 5 November 1996