BALD EAGLE NESTING IN RELATION TO HUMAN DISTURBANCE SOURCES IN THE LAKE ALMANOR REGION, CALIFORNIA

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Abstract: I evaluated bald eagle (*Haliaeetus leucocephalus*) population parameters and human disturbance at 3 reservoirs within the Lake Almanor area (*sensu* U. S. Fish and Wildlife Service [1986]). I evaluated sources of human disturbance and bald eagle nest populations, reproduction, and nest locations, to assess whether human activities were detrimentally affecting eagles. Eagle populations were characterized by population size and rate of growth during 1988-2006 at reservoirs with different levels of human development. I examined territory age, nest occupancy, nesting success, and productivity of recent nests (1997-2006) in relation to the distance of nests from human disturbance sources, including: high-use paved roads, residences, and highly developed areas. The known eagle population increased by 67% (from 9 to 15 pairs) between the 1980s and 2006 and has met the Recovery Plan objective. Most of the population increase occurred at Lake Almanor, the largest and most developed reservoir. A high proportion of nests within newer territories were closer to sources of human disturbance than are older nests. Average nesting success and productivity was equal or higher for nest territories closer to human facilities than for those farther away. Eagles at newer territories were more successful and productive than pairs at older territories. Several recently established territories showed substantial tolerance of human activity close to nest sites. Overall, the population shows no indications of being detrimentally affected by human disturbance. The establishment of new territories in areas closer to human disturbance sources, and the higher reproductive success of these nests, suggests that these territories are high quality habitat and that the population as a whole is developing greater tolerance for human disturbance. Many newer nests are located closer to sources of disturbance than the recent standard prescribed buffer for eagle nests but farther away than new national nest protection guidelines, suggesting that nest protection efforts should incorporate recent local information.

TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 43:19-26; 2007

Key words: bald eagle, development, *Haliaeetus leucocephalus*, human disturbance, California, reproduction.

Bald eagles are sensitive to human disturbance, but the degree of sensitivity varies among populations and individuals (Anthony and Isaacs 1989, Beuhler 2000, Jackman and Jenkins 2004). Understanding eagle responses to human disturbance and the facilities that result in increased human use in bald eagle habitats is important for eagle management. Notwithstanding the recent delisting of the bald eagle under the federal Endangered Species Act (ESA; U. S. Fish and Wildlife Service 2007a), continued information is needed on eagle responses to disturbance. In association with its delisting decision, the U. S. Fish and Wildlife Service (USFWS) also issued rules defining disturbance under the Golden and Bald Eagle Protection Act (U.S. Fish and Wildlife Service 2007b), which could continue to be the basis for eagle protection. The Service also issued a set of voluntary guidelines for protection of bald eagle nests (U.S. Fish and Wildlife Service 2007c). These guidelines proposed protection buffers of 108-216 m (330-660 ft), which are substantially less than the 0.9 km (0.5 mi) that had been typically required by the USFWS prior to delisting (C. Goude, USFWS, personal communication). It is unclear to what extent the National Guidelines will be employed in local recommendations for eagle protection.

This study explores the geographic relationships between different human facilities (roads, individual human residences, and major development) and bald eagle occurrence and productivity. I evaluated eagle nests in the Lake Almanor area to better understand the responses of eagles to sources of human disturbance. Goals of this evaluation were to: 1) describe changes in human disturbance (i.e., human development) in the study area and population responses of nesting bald eagles, 2) describe the range of human use conditions in the vicinity of bald eagle nests in the area, and 3) evaluate nest success and productivity of eagle pairs nesting at sites with different levels of disturbance. I tested the hypotheses that bald eagle occurrence, nesting success, and productivity would be adversely affected by higher

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levels of human disturbance (as determined by distance to sources of human disturbance).

STUDY AREA

The Lake Almanor area (U. S. Fish and Wildlife Service 1986) includes 3 hydroelectric reservoirs (Lake Almanor, Butt Valley Reservoir, and Mountain Meadows Reservoir) operated by Pacific Gas and Electric Company (PG&E) that support most of the nesting bald eagles in this area. Conifer forest occupies much of the area surrounding these reservoirs. Large meadows also occur at Lake Almanor and Mountain Meadows Reservoir.

Levels of development vary among the reservoirs. Butt Valley Reservoir is most isolated, with development limited to hydroelectric facilities and minor recreation facilities. Mountain Meadows Reservoir lacks any development on the shoreline, except for hydroelectric facilities and wastewater treatment ponds, but is adjacent to the town of Westwood and community of Clear Creek. Lake Almanor supports the most development, including the town of Chester, and residential developments between Highway 36 and the Hamilton Branch, and along Highway 89 on the west side of the lake. Lake Almanor, however, is a large reservoir, and despite its extensive development, much of the shoreline and adjacent area remains undeveloped.

METHODS

Changes in Development and Eagle Populations

I evaluated the relationship between human development and the size of the eagle nesting population within the study area. I evaluated patterns for each of the 3 major reservoirs over the 19-year period of 1988-2006, based on data provided by PG&E (R. E. Jackman, Garcia and Associates, personal communication). I also evaluated the recent trend in eagle numbers over the last 10 years (1997-2006) to determine if any recent changes in eagle numbers were associated with recent development.

For the population analysis, I characterized development based on available information and my personal knowledge of local land use patterns. I conducted this analysis at a generalized time scale because most development projects have built out over a period of many years (M. Williams, U. S. Forest Service, unpublished report; D. Airola, personal. observation.). Thus, the primary analysis was to compare changes in eagle populations with the relative extent of development in lands surrounding the 3 major reservoirs (nearly absent at Butt Valley and Mountain Meadows Reservoirs and higher at Lake Almanor). The tested hypothesis was that eagle populations have declined or grown at a slower rate at reservoirs with higher levels of development, suggesting human interference with eagle populations.

Nest Locations and Reproduction in Relation to Human Activity

This analysis characterized nest locations and reproduction at nests at different distances from sources of human disturbance and among territories of different ages. I used the following methods to identify nest locations and territory ages, evaluate nesting success and productivity, and characterize disturbance. *Nest Site Locations*: Nest site locations were provided as UTM coordinates by PG&E (R. Jackman, personal communication). *Territory Ages*: I compared nest site locations, reproduction, and human disturbance at older, established nest territories (known before 1995) to newer territories that have been detected since 1995. The newer territories may have been established in a year prior to their discovery. However, given the long history of continuous eagle surveys in the Almanor Basin (PG&E unpublished report; M. Williams unpublished report), it is likely that most territories discovered in this recent period are newer than those found earlier, some of which have been known as far back as the 1960s (M. Williams unpublished report; D. A. Airola, unpublished data). *Nesting Success and Productivity*: Data on nest territory occupancy, success, and productivity were acquired during aerial surveys conducted by PG&E using methods described by Jackman and Jenkins (2004). Data on nest site occupancy and reproductive success were taken from a summary by PG&E (unpublished report), updated by Jackman (personal communication). I characterize nest status and reproduction used the following categories (from Jackman and Jenkins [2004]): Occupied - presence of a nesting pair in the territory; Successful - presence of at least one young during the last aerial survey; Productivity - the number of young produced annually per nesting pair.

I summarized average nesting success and productivity for the 10-year period from 1997-2006. This period was selected as a balance between encompassing an adequate sample of years to characterize average nest success and evaluating reproductive performance under recent human-use conditions. Nest success and productivity for territories discovered during this period were based on the number of years for which data were available.

Characterizing Human Disturbance

I quantified potential human disturbance near bald eagle nests based on the distance from nest sites to 3 types of human features: high-use paved roads, individual buildings (“residences”), and major develop-

ment areas, as characterized below. *High-Use Paved Roads*: (hereafter, "roads") State and local highways that receive frequent traffic. All paved roads in the area were considered high use, except the access road to Butt Valley Reservoir, because it received notably lower use than most other paved roads. *Nearest Residence*: any human residence, whether within a major development area or isolated. *Major Development Areas*: larger areas of existing high-density residential and commercial development. Major development areas included the towns of Chester and Westwood, and the communities of Hamilton Branch, Clear Creek, Almanor West, Bailey Creek Estates, Lake Almanor Peninsula, and the Prattville/Plumas Pines Resort area. Other areas with fewer residences (generally <1 per acre) and little or no commercial development were characterized as low-density residential areas.

I mapped development as linear features and polygons, based on first-hand knowledge of the project area and examination of aerial photography via Google Earth (www.earth.google.com). I manually measured the extent of the shoreline area within 1.6 km of reservoirs in major development and low-density residential areas. I calculated distances from nests to disturbance features by the ESRI ArcGIS 9.1 geographic information system (GIS). I visited several nests that were closest to disturbed areas ("Switchback" and "Feather River") to more precisely determine distances to human features using a measured pace.

Following measurement of distances to human features, I made a post-hoc assignment of nest sites to the disturbance categories high (<1.0 km) and low (>1.0 km) based on natural discontinuities in these distances (see ***Results***). This categorization allowed evaluation of colonization patterns and reproduction in relation to these 2 relative disturbance levels. If less disturbed sites showed a higher incidence of colonization by new pairs and higher levels of reproduction as measured by nesting success (average % of nests successful) and productivity (average number of young/occupied nest/year), this result would support the hypothesis that bald eagles were exhibiting sensitivity to human disturbance.

Territory Age and Distance from Human Disturbance

I assumed that new pairs of eagles had a choice in selecting from suitable nest sites available near to (<1 km) or far (>1 km) from potential human disturbance sources. Therefore, if disturbance were affecting nest site selection, this should have been evident in the distances of recent nest sites from sources of human disturbance. I compared distances of older (<1995) and more recently established territories from sources of human disturbance to determine if newly established pairs had located nest sites closer to human disturbance than eagles at older territories.

Reproduction and Territory Age

I used nesting success and productivity to assess potential effects of human disturbance on the bald eagle population. If human disturbance were detrimentally affecting bald eagle populations, I expected that nests closer to sources of disturbance would have lower nesting success and productivity than nests farther away from such sources. I also evaluated reproductive performance for older and more recently established territories to determine if reproductive data suggested detrimental effects of human disturbance or, alternatively, that newer pairs may be habituating to human activity. This comparison also was used to evaluate the alternative hypothesis that older territories, which potentially support older birds, are less productive than new territories that may support younger birds.

RESULTS

Changes in Developed Area

Development is most extensive near Lake Almanor, and is limited near Mountain Meadows Reservoir and nearly absent at Butt Valley Reservoir. At Lake Almanor, high-density residential and commercial development occupies 34% of the 80-km perimeter shoreline at Almanor, while low-density residential areas comprise 12%. An additional 14% of the shoreline has no residential or commercial development but has highways located nearby, and the remaining 40% is essentially undeveloped. Most residential developments were approved and initially developed prior to the 1980s, although many of these areas have continued to build out since then. Commercial development has expanded slowly in Chester, although the nearby shoreline remains mostly undeveloped. The only major new developments since the 1980s are the 240-ha Bailey Creek Estates residential development, located 1.0-2.5 km away from the lakeshore and only partially built out, and the Chester Airport runway expansion (M. Williams, unpublished report).

No shoreline development is present at Mountain Meadows Reservoir, except the limited PG&E hydroelectric facilities. The town of Westwood is 1.2 km from the nearest portion of the lakeshore. Butt Valley Reservoir has no development other than hydroelectric and limited recreation facilities.

Changes in Eagle Populations

The known nesting eagle population in the study area has increased by 67%, from 9 territories during 1988-1991 to 15 during 2003-2006 (Table 1). Includ-

Table 1. Number of young bald eagle produced per territory in the Lake Almanor area, California 1988-2006. Abbreviations are NO = Not occupied, NS = Not surveyed, and OSU = Occupied, success unknown.

Reservoir	Nest territory	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Butt Valley	Butt Valley Dam	0	NO	1	0	0	2	1	0	2	1	2	0	0	0	1	0	1	0	0
	Cool Springs	2	0	NO	NO	1	2	2	0	2	0	0	0	0	0	1	0	2	0	0
	Gravel Island																2	2	2	2
	Butt Valley Dam II	2	2	2	1	OSU	2	2	0	2	2	1	1	1	2	1	0	0	0	0
Lake Almanor	Rocky Point	0	0	0	NS	0	NO	0	0	0	1	2	1	1	2	0	0	1	1	0
	Switchback										2	0	1	2	1	0	0	2	0	0
	Rock Lake									0	1	1	2	1	1	0	0	0	0	0
	Collins South	NS	OSU	NO	1	2	NS	NO	2	2	2	2	2	0	1	2	0	1	2	0
	Collins North	0	0	NO	0	0	OSU	0	1	0	NO	0	2	0	NO	NO	1	NO	0	0
	Feather River								2	2	2	2	NO	1	2	1	1	1	0	2
	Mud Creek Rim	NS	1	2	1	0	0	2	NO	0	2	1	1	1	2	2	0	0	1	0
	Bailey Creek														0	1	0	2	1	1
	Eastside											2	2	2	1	3	1	3	0	0
Mtn Meadows	Mountain Meadows West	0	0	OSU	OSU	0	NS	NS	0	1	2	1	0	0	0	0	0	0	0	0
	Mountain Meadows East	2	OSU	NS	NO	NO	NS	NS	NO	NS	0	NO	NO	NO	NO	2	0	0	0	0
Summaries	Total territories	9	9	9	9	9	9	9	10	11	12	13	13	13	14	14	15	15	15	15
	Total occupied territories	7	8	5	6	8	6	6	8	11	11	11	12	12	12	13	15	14	15	15
	Occupied territories, known outcome	7	6	4	5	7	4	6	8	10	11	11	12	12	12	13	15	14	15	15
	# young	6	3	5	3	3	6	7	5	11	15	12	13	10	11	14	5	14	9	4
	# successful territories	3	2	2	3	2	3	4	3	6	9	8	9	7	8	9	4	8	6	3
	% successful	43	33	50	60	29	75	67	38	60	82	73	75	58	67	69	27	57	40	20
	Ave # young/occupied territory	0.9	0.5	1.2	0.6	0.4	1.5	1.2	0.6	1.1	1.4	1.1	1.1	0.8	0.9	1.1	0.3	1	0.6	0.3

ing the Stump Ranch territory (which is away from major reservoirs and thus not addressed in this analysis), the designated Almanor Recovery Zone (U. S. Fish and Wildlife Service 1986) has met its recovery goal of 16 active territories.

Changes in the number of territories since the 1980s have varied among reservoirs. The number of territories at Lake Almanor has increased from 4 to 9, while the numbers increased from 3 to 4 at Butt Valley and remained at 2 over the entire period at Mountain Meadows. The pattern of strongest increase at Lake Almanor does not support the hypothesis that disturbance over the last 19 years has been detrimental to nesting bald eagles.

Nest Site Occupancy, Nesting Success, and Productivity

Nest site occupancy was high at nearly all sites over the last 10 years, averaging 94%. Average annual nesting success varied widely among territories from 17% to 100% of nesting attempts (average = 56%). Similarly, average annual productivity (young/occupied nest) varied widely among territories, from 0.3 to 2.0, with a population average of 0.8. Average nesting success and productivity over the last 10 years were affected by low reproduction in 3 of the years between 2003 – 2006 (Table 1). Low nesting success and productivity in 2006 was attributed to extreme snow and rain conditions during the early nesting season (M. Williams, personal communication).

Nest Locations in Relation to Disturbance

Distances of nests to facilities (roads, nearest residence, major development) that could serve as sources of human disturbance varied widely among nest sites, especially between newer and older territories (Table 2). Five of 6 newer nests (83%) were close (<1 km) to roads, but only 3 of 9 older nests (33%) were close (Fisher exact text, $P = 0.08$). Similarly, 5 newer nests (83%) and only 1 (11%) of the older nests were close to residences ($P = 0.01$), while 4 new nests (67%) and no older nests were near major developed areas ($P = 0.01$).

Table 2. Ages and distances from human facilities of nest territories of bald eagles in the Lake Almanor area, California. For territory age (Age), Older = known present before 1995 and Newer = detected since 1995. For distance categories, L = ≤1.0 km and H = >1.0 km.

		Distance To Paved Road		Distance To Residences		Distance To Major Developed Area	
Nest Territory	Age	Km	Category	Km	Category	Km	Category
Butt Valley Dam	Older	8.3	H	9.5	H	12.7	H
Cool Springs	Older	7.8	H	8.2	H	11.0	H
Gravel Island	Newer	6.4	H	6.9	H	9.4	H
Butt Valley Dam II	Older	6.8	H	7.6	H	11.1	H
Rocky Point	Older	0.3	L	2.4	H	6.6	H
Switchback	Newer	0.4	L	0.3	L	0.4	L
Rock Lake	Newer	0.5	L	0.5	L	0.6	L
Collins South	Older	0.5	L	1.6	H	1.6	H
Collins North	Older	0.6	L	1.0	L	2.4	H
Feather River	Newer	0.06	L	0.2	L	0.5	L
Mud Creek	Older	1.7	H	2.4	H	3.9	H
Bailey Creek	Newer	1.0	L	1.0	L	1.0	L
Eastside	Newer	0.6	L	0.5	L	3.0	H
Mountain Meadows West	Older	2.7	H	2.3	H	2.2	H
Mountain Meadows East	Older	7.7	H	7.2	H	7.3	H
Averages		0.5		0.5		1.1	

These results are contrary to those expected if increased levels of human disturbance were affecting nest site selection by bald eagles in the area.

Average distances from 5 recently established Lake Almanor nests to human facilities were closest for roads and residences (0.5 km) and greater for major development (1.1 km, Table 2). These nest distances, however, do not demonstrate the spacing preferences of eagles from each facility, because they also partly reflect the amount and location of facilities around the lake (see ***Changes in Extent of Development*** above*)* rather than eagles' responses to them. Compared to the standard USFWS recommendation for a 0.9-km buffer between eagle nest and development, nests in 7 (78%) of 9 eagle territories at the more heavily developed Lake Almanor were found ≤0.9 km from major roads, while 4 (44%) were ≤0.9 km from a residence, and 3 (33%) were ≤0.9 km from major development. Most (4) of the nests closer than the 0.9 km buffer to roads and all of the nests closer to residences and development were newer nests.

Nesting Success and Productivity in Relation to Disturbance

Evaluation of nesting success and productivity at nests nearer to and farther from sources of human disturbance indicate that average nesting success was 9-16% higher for nest territories closer to the 3 types of human facilities than for those that were further away (roads: 63% versus 48%, residences: 61% vs. 52%, and major development: 64% to 52%). Similarly, but less dramatically, average productivity for nests located close to the 3 disturbance sources ranged from 0-25% higher than for more distant nests (roads: 0.8 versus 1.0, residences: 0.8 versus 0.9, and major development: 0.9 to 0.9). These patterns of nest success and productivity in relation to distance from disturbance sources do not support the hypothesis that bald eagles are being detrimentally affected by human disturbance in the study area.

Several examples of accommodation of human disturbance by nesting bald eagles are notable. The Feather River territory was first detected in 1995. The active nest in this territory was located only 65 m from a major public road and across the street from a large church. An informal but regularly used course for motocross, 4-wheeling, and snowmobiling was present in the nest area at the time of discovery. Currently, the course has 2 tracks that are banked on either side of, and immediately up against, the nest tree. Since its discovery, this nest has shown a 90% occupancy rate during the 10-year period and the second highest rate of nesting success (89%), and is within the top 4 territories in productivity (1.2 young per occupied nest) (Table 2). The Switchback territory was occupied by eagles in 1997 during the winter lull between construction seasons of the paved Almanor all-weather trail (M. Williams, personal communication). The nest was located within a hillside switchback in the trail so that the trail formed a 270 degrees arc within 15 m of the nest tree. Nest occupancy has been high (100%), while nesting success (55%) and average annual productivity (0.9 young per occupied nest) have been close to the average values for the population as a whole (61% success and 0.9 productivity) (Table 2).

Nest Success and Territory Age

Average nesting success during 1997-2006 was 28% higher for pairs at newer territories (72%) than at older territories (44%). More dramatically, productivity was 80% higher at newer territories than at older territories (1.17 vs 0.65 young/occupied nest).

DISCUSSION

Results from this study indicate that the bald eagle population in the Lake Almanor area has not been detrimentally affected by past and recent development activity. The eagle population is increasing primarily at Lake Almanor, the most developed reservoir. Newly established territories tend to be closer to potential sources of human disturbance than are the older nests. Reproductive success and productivity also are equal or higher at nests closer to sources of disturbance than for nests further from such areas. Also, several recent territories in area of high human use (Feather River and Switchback) show average or high levels of occupancy, reproductive success, and productivity.

The reasons for higher population growth at Lake Almanor, compared to Mountain Meadows Reservoir and Butt Valley Reservoir, are unknown. They may have to do with a greater amount of lakeshore habitat because of its larger size, but other differences in nesting habitat conditions (e.g., availability of large trees suitable for nesting), food supply, or other factors could also be involved. The fact that nesting success and productivity was higher at nests that are closer to sources of human disturbance than those further away, however, does not demonstrate that human presence is beneficial to nesting bald eagles. Rather, other factors could be involved, including the possibility that newer territories support more fecund younger adults or that newer nests are closer to more productive lakeshore habitats that improve foraging efficiency.

This analysis does not address several other factors that could be influencing nesting success, including residual effects of past pesticide contamination (Risebrough and Jarman 1985) and age of individuals (Jenkins and Risebrough 1995, Jenkins and Jackman 2006). Increased competition as populations increase also has

been documented to reduce productivity of regional eagle populations (Hansen and Hodges 1985). This effect, however, would seem likely to be spread across all territories rather than concentrated on older territories. Also, although relatively low reproduction over the 4 most recent years might suggest effects of competition, productivity tends to be higher at Lake Almanor, where most of the population increase has occurred.

Several alternative reasons could explain why recently established bald eagle nest territories have tended to be located closer to potential sources of human disturbance (roads, residences, and developed areas) than are the older nests. First, eagles could have been forced to occupy more developed areas as a result of lack of suitable nest trees in less-disturbed areas. Alternatively, eagles could have become more acclimated to human activity and now accept areas with higher human use than they did previously. Available information, including the reservoirs selected by new birds, territory occupancy rates, reproductive success, and productivity, does not support the view that eagles have been forced into poor quality habitat. Rather, the information supports the explanation that eagles have become more accepting of human activity, and their use of habitats that previous generations of eagles may not have accepted has allowed the population to expand and permitted new colonists to produce vigorously. Most likely, eagles are selecting areas closer to sources of human use facilities because these areas also are closer to the lakeshore, thereby enhancing efficiency of foraging and nest territory defense. Notably, older territories in this area were likely established away from the lakeshore as a result of disturbance by timber harvest (Thelander 1973). Enactment of nest protection measures (e.g., Forbis et al. 1977) has reduced timber harvest conflicts on both private and public lands, but the older territories have remained in the same areas (M Williams, unpublished report, Airola unpublished data).

Availability of suitable nest trees could be another influence on distribution of nesting eagles. The characteristics of trees used for nest placement by bald eagles (Lehman 1979) do not appear to have changed over the study period since the 1970s. All eagles continue to nest in very large mature trees (usually pines) with large branches that are arranged in an open pattern (M. Williams unpublished report; Airola unpublished data.). Data are not readily available on the distribution of suitable nesting trees in the watershed, but it seems likely that larger trees are more common in areas away from roads and other sources of disturbance, because developed areas tend to occur on flatter ground that was less expensive and easier to log.

MANAGEMENT IMPLICATIONS

This analysis strongly supports the view that the bald eagle population has not been detrimentally affected by the moderate level of development that has occurred in recent years in the Lake Almanor area. The study demonstrates that, as a whole, new eagle pairs are accepting areas closer to human disturbance than older pairs did in the past. These findings, however, are general, and do not specifically address the buffer distances required to protect bald eagles.

Many newer nests are located closer to human facilities than the previous recommended 0.9-km buffer distance and show high levels of nest site occupancy and nesting success. This result indicates that recent individual pairs are demonstrating a greater ability to tolerate disturbance than was perceived for previously established pairs. The extent to which older pairs are now able to tolerate higher levels of disturbance, and whether tolerance has increased, is confounded by the pairs' strong fidelity to established breeding sites (see Jenkins and Jackman 1993, 2006). It is possible that by remaining in relatively undisturbed sites, older pairs have not developed as much tolerance as birds in newer territories, although they also have been exposed to increased human use during foraging and resting activities away from their more remote nest sites.

This analysis provides some basis for evaluating the recent national guidelines for bald eagle protection (U. S. Fish and Wildlife Service 2007b). Although distances of many nests from sources of disturbance in the Lake Almanor area are less than the previous 0.9 km standard recommendation, all but one are at a greater distance than the 0.1-0.2 km distance recommended in the national guidelines. These results suggest the utility of continuing to use locally-derived, up-to-date information in determining protection buffers for eagle nests.

ACKNOWLEDGMENTS

Collection of data used in this analysis was funded by PG&E as part of hydroelectic project compliance. Special thanks to J. M. Jenkins and R. E. Jackman for collecting these data and making them available, M. Williams for providing nest site locations and histories of several recent territories, and R. Harris for comments and encouragement. G. Gallagher conducted GIS analysis. N. Ceaglio and J. Duffy provided information on land developments and recreation uses. D. Garcelon and D. Germano provided helpful review comments. R. E. Jackman, J. Estep, and D. Clyde provided helpful comments on previous drafts. C. MacVitie assisted with manuscript preparation. The study was partly funded by Dyer Mountain Associates LLC.

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