State of California
THE RESOURCES AGENCY
Department of Fish and Game

DEVELOPMENT OF TECHNIQUES FOR RAPTOR MANAGEMENT, WITH EMPHASIS ON THE PEREGRINE FALCON

by

Brian James Walton
Western Foundation of Vertebrate Zoology
c/o Coast Range Biological Research Institute
Santa Clara, California

Wildlife Management Branch
Administrative Report No. 77-4
August, 1977

DEVELOPMENT OF TECHNIQUES FOR RAPTOR MANAGEMENT, WITH EMPHASIS ON THE PEREGRINE FALCON[1/]

by

Brian James Walton
Western Foundation of Vertebrate Zoology
Los Angeles, California

ABSTRACT

The raptor management techniques of double clutching, augmentation, and fostering were further developed in this study by testing their application on a population of prairie falcons in the Coast Ranges of California.

Manipulation at 19 prairie falcon and 1 peregrine falcon nesting territories, observations at 43 prairie falcon nesting territories as a control, and laboratory incubation, hatching, and brooding of prairie falcon eggs or young, was conducted.

Fifty-seven prairie falcon eggs were manipulated. Forty-four were fertile, 13 were addled, 10 were hatched by prairie falcons in wild nests, and 21 were hatched in the laboratory. Nineteen of the young hatched in the laboratory were later released in wild nests, one died before release and one young was returned to a captive breeding project.

The double clutching technique was tested at six territories. Four pairs of wild prairie falcons recycled and laid replacement sets of eggs.

Augmentation of egg clutches was tested at two territories. At a combination of these two territories and one recycling territory, egg production was increased from 11 to 16 eggs; 15 young fledged. Augmentation of broods was tested at five territories. The number of young was increased from 15 to 30 young; 29 fledged.

Fostering of young was tested at two territories. All foster young fledged. Cross-fostering was tested by placing young prairie falcons in a peregrine falcon nest. This test was successful.

At three territories, captive-bred or captive-incubated young were released replacing young that had been moved in augmentation tests. At one territory, young were removed for augmentation but were later returned when no synchronous nest was located.

This study was designed to develop optimum methods for application of the three raptor management techniques in California. The study was not designed to increase the productivity of the study area population of prairie falcons; however, 13 additional young were produced as a result of the manipulations in this study, an increase of 21 percent.

Productivity and annual cycle of prairie falcons in the study area was provided for the period 1972 to 1977.

1/ Supported by Federal Aid for Endangered, Threatened and Rare Fish and Wildlife, Nongame Wildlife Investigations, Project E-1-1, Study V, Job 1.61, Wildlife Management Branch Administrative Report No. 77-4 (August 1977).

RECOMMENDATIONS

As a result of this study, it is recommended that the Department of Fish and Game:

1. Resurvey the 1977 manipulated and control prairie falcon nesting territories in 1978, to further evaluate the techniques tested.

2. Implement management techniques to enhance remnant populations of peregrine falcons, and consider their use to enhance bald eagle and California condor populations.

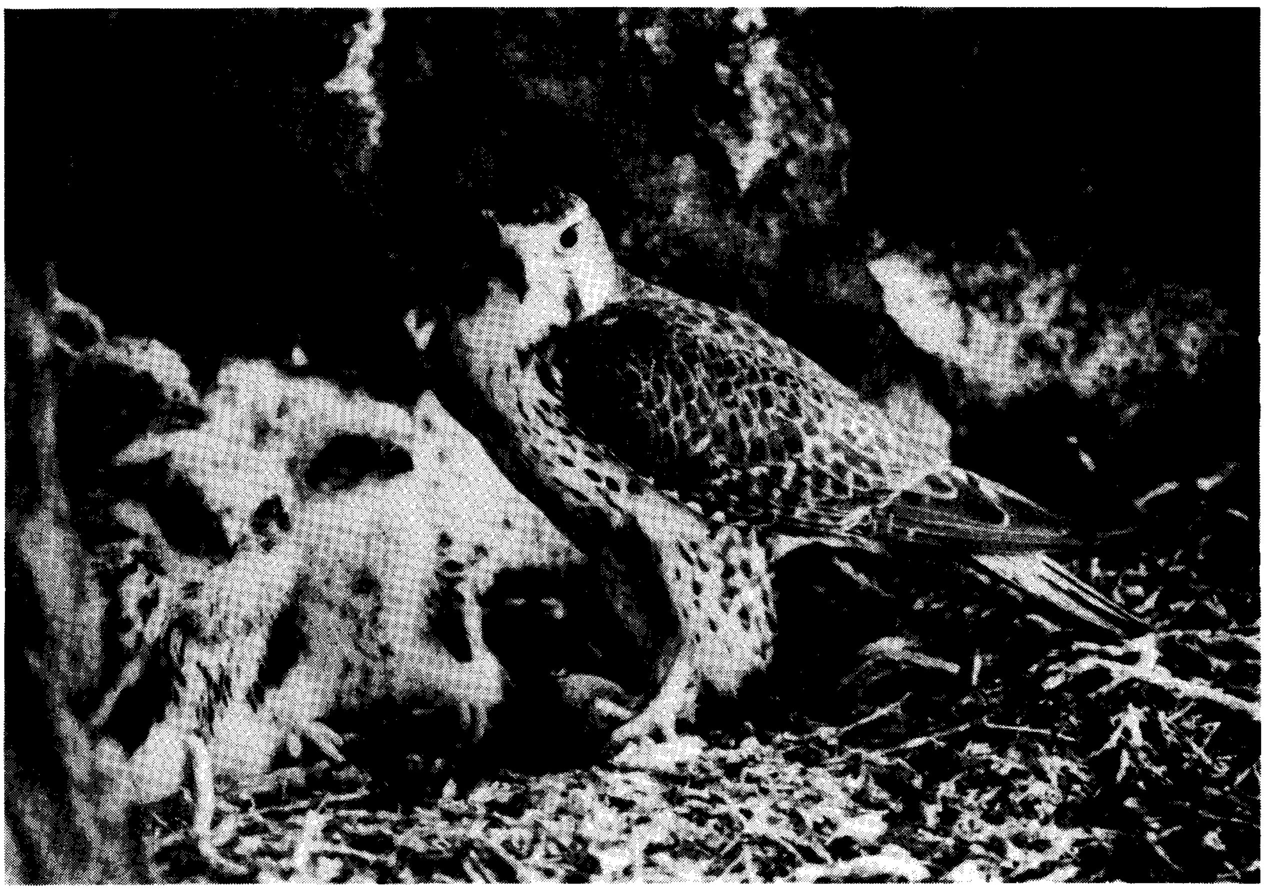
3. Support captive raptor breeding programs to insure a source of raptors to augment declining or endangered raptor populations.

4. Survey raptor populations to determine clutch size, brood size, and nesting territory occupancy in geographical areas selected for management in the future.

INTRODUCTION

The study of raptorial birds has increased in recent years in response to the need for knowledge concerning declines in their populations. Three species of raptor in California have declined in numbers so severely that they required protection through state and federal endangered species legislation (Leach et al., 1976). These species include the American peregrine falcon (Falco peregrinus anatum), the southern bald eagle (Haliaeetus leucocephalus leucocephalus), and the California condor (Gymnogyps californianus). All three species have declined due to losses of nesting habitat (Thelander, 1973, 1976; Wilbur, in press) and reduced reproductive success due to eggshell thinning (Sprunt, 1969; Thelander, 1976; Wilbur and Kiff, in press). Recovery teams have been appointed by the Secretary of the Interior to develop recovery plans for the management of two species -- American peregrine falcon and California condor. Plans are expected to promote the recovery of each species to stable population levels.

Until recently, management of raptorial birds was primarily limited to: 1) the protection of breeding pairs and their nests, and 2) the formation of refuges and ecological reserves. Techniques to increase the productivity of remnant endangered raptor populations have recently been developed by The Peregrine Fund of Cornell University, Canadian Wildlife Service, and Colorado Division of Wildlife. This study involves further development of the techniques of double clutching, augmentation, and fostering, and also, determination of the feasibility of their application on California raptor populations. Emphasis is on the development of methods to increase the productivity of peregrine falcons in California.



Adult female prairie falcon at eyrie (photo by Rick Kline).

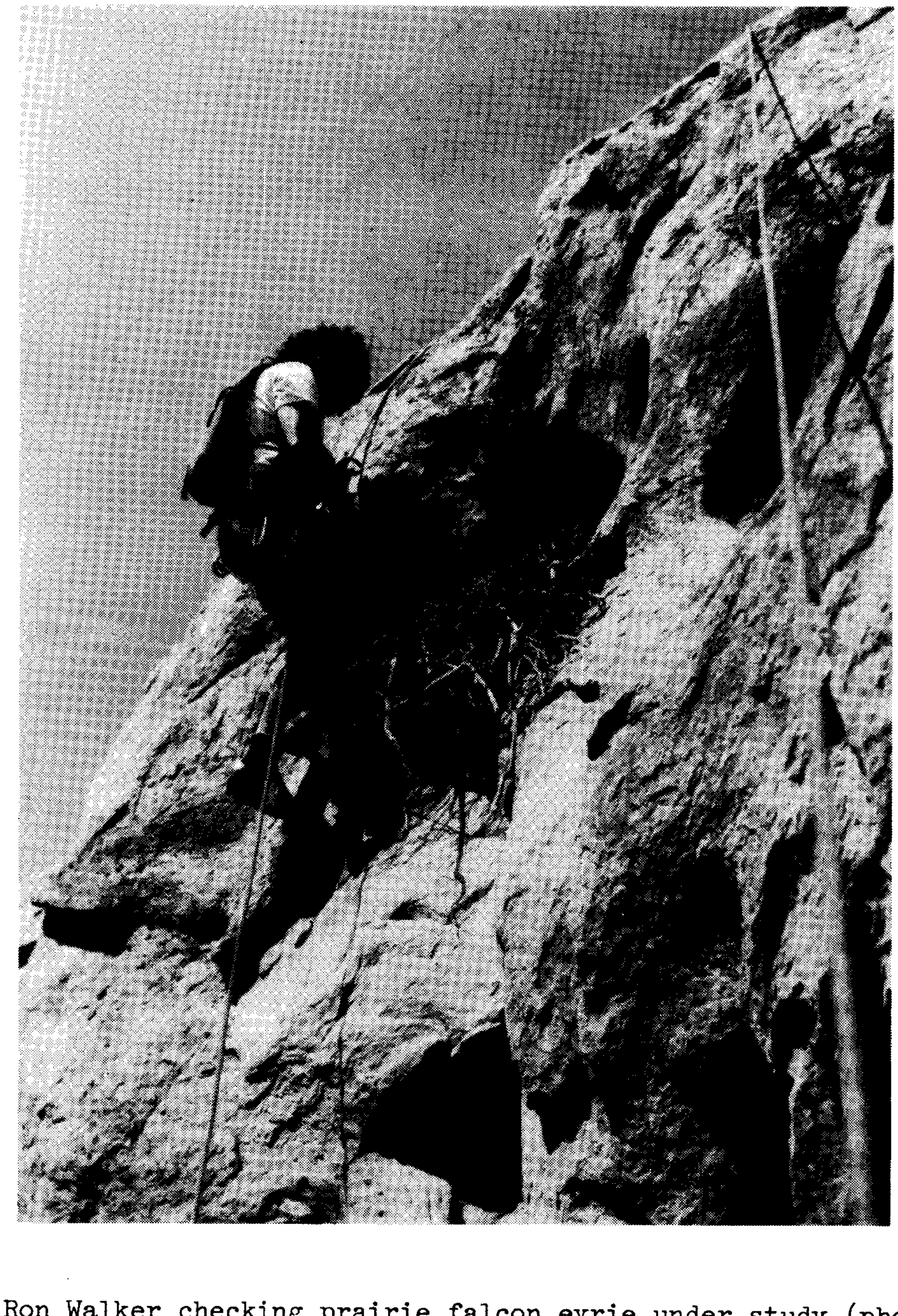
From 1972 to 1977 the prairie falcon (*Falco mexicanus*) population was studied in the southern Coast Ranges of California (Walton, in prep.). The population of prairie falcons in this study area (Figure 1) was selected for this study to develop raptor management techniques on the basis of three criteria: 1) similarities in the nesting natural history and ecology between the prairie falcon and the peregrine falcon, 2) extensive historical information on nesting territories of both species, and 3) abundance and apparent stability of the prairie falcon population.

FIGURE 1. Distribution of prairie falcon nesting territories manipulated in the Coast Ranges study area in California, 1977.

METHODS AND MATERIALS

This study was conducted between February and July, 1977. To develop population manipulation techniques, a variety of field and laboratory methods were applied. Fifteen people were actively involved in various phases of the study.

Forty prairie falcon nesting territories, which have been studied from 1972 to 1977, were selected as potential territories for study. These territories were visited in February and March to determine prairie falcon occupancy. A final selection of 10 active nesting territories for manipulation study was based on: 1) the ease of access, 2) feasibility for mountaineering, and 3) history of productivity. These nesting territories were observed on a regular basis from a distance exceeding 500 m. Territories were observed to determine specific dates for egg-laying, onset of incubation, and hatching of eggs. Nesting territories were visited on four or five occasions and nests were climbed one to five times.



Biologist Ron Walker checking prairie falcon eyrie under study (photo by Brian Walton).

An additional forty prairie falcon nesting territories, which were also studied from 1972 to 1977, were selected as a control for comparison of productivity with the manipulated territories. Three new territories found for the first time in 1977, were added to the control sample.

Eggs collected from wild nests were placed in egg containers designed for backpackers. Eggs placed in containers were padded with cotton, to eliminate jarring, and were carried in a backpack to the bottom of the nesting cliffs where they were placed in portable, 12 volt incubators for transport. The eggs were maintained at a temperature of 20° to 30° C while in transport. Transportation time ranged from two to nine hours. Depending on road conditions, eggs occasionally received a great deal of shaking. Eggs were placed in Marsh Farms Roll-X forced air incubators in the laboratory and maintained at a temperature of 37° C and a relative humidity of 35 percent. The incubator turned the eggs automatically once each hour. Eggs were weighed and candled daily, when possible, to record embryonic development.

Infertile and addled eggs were also collected for pesticide analyses and eggshell measurements (Walton, in prep.). Dummy eggs were temporarily placed in one wild nest. These were fresh, infertile, captively produced prairie falcon eggs.

Eggs donated by captive breeding projects were incubated under the same conditions as the eggs collected at wild nests. Two eggs that were collected at wild nests were partially incubated under a captive falcon.

Prior to pipping, eggs were transfered to a Hovabator still-air hatcher and maintained at a temperature of 36.5° C and a relative humidity of 80 percent. After hatching, the young were left in the hatcher for six to eight hours to rest and dry off. Young were later transferred to still-air brooders for one to five days. They were fed finely ground small birds that were trapped from San Luis Obispo County vineyards under a depredation permit.

Before one week of age, young prairie falcons were placed in a breeding chamber (2.5 m wide, 5 m long, 2.5 m high) where they were fed and brooded by a pair of prairie falcons that has successfully raised their own young for three years. The length of time that young were brooded by captive falcons ranged from 3 to 21 days.

Young, when being transported, were fed by a biologist with a puppet simulating an adult prairie falcon. Young were transported from the laboratory and released in wild prairie falcon nests; young were also moved between wild prairie falcon nests. Young were transported in portable 12 volt brooders and maintained at a temperature of 20° to 30° C.

Prairie falcon eggs were collected at a variety of stages in incubation. Young prairie falcons were moved or released at a variety of stages in development.

The detailed methods used to incubate, hatch, and brood the prairie falcon eggs and young are those developed and implemented by biologists of The Peregrine Fund (Cade et al., in press).

All eggshells and fragments were deposited at the Western Foundation of Vertebrate Zoology, Los Angeles.

Photographs were taken of all field work, laboratory activities, and equipment; slides are on file with the Department of Fish and Game.

A glossary of definitions is provided.

Each nesting territory was assigned an identification code consisting of an abbreviation for the county in which it was located, and a number corresponding to the sequence they were initially visited. For example, K-1 is the first territory that was visited in Kern County; SLO refers to San Luis Obispo County; SB refers to San Benito County; and M refers to Monterey County. Nesting locations for the control and manipulated territories are on file with the Department of Fish and Game.

RESULTS AND DISCUSSION

Control Territories

Information regarding the prairie falcon historical nesting territories, currently occupied nesting territories, clutch and brood size, fledging success, and the annual cycle for prairie falcons in the Coast Ranges study area from 1972 to 1977 is presented in Tables 1 and 2. Information on historical and recent nesting activities is a result of a combination of surveys including: 1) field research on an annual basis over six years in the Coast Ranges study area, 2) examination of museum oological data, 3) field notes of oologists, and 4) personal communications with ranchers, falconers, naturalists, government biologists, and academicians, who have a long term familarity with the study area.

Garrett et al. (1973) studied this area as part of a statewide prairie falcon survey. He reported that occupancy in the region near California's Central Valley was well below historical levels. Since that time the prairie falcon occupancy of that region of the study area, and the other regions of the study area, have been similar to historical levels (Truesdale, field notes). Productivity within the study area since the report by Garrett has been similar to historic levels for other prairie falcon populations.

Forty-three nesting territories were observed as a control for comparison with manipulated territories in 1977. Clutch size for the control territories was slightly higher in 1977 than over the previous five year period. Clutch size for the manipulated territories, 4.1 eggs per clutch, was slightly lower than that for control territories, 4.6 eggs per clutch. However, after manipulation the fledging success for the manipulated territories, 3.2 young per nest, was nearly as high as that for the control territories, 3.3 young per nest (Table 1).

TABLE 1. Productivity of prairie falcons in the Coast Ranges study area in 1972 through 1976[a] and in 1977.

	1972-1976 5 yr. Average	1977 Controls	1977 Manipulated
Number of known historic nesting territories	173[b]	173	173
Number of territories visited per year	37	43	19
Mean clutch size (range 2-5, 34%= 5)	4.4 (65)[c]	4.6 (18)	4.1 (19)
Mean brood size (range 0-5, 24%= 5)	3.35 (79)	3.5 (23)	3.28 (19)
Fledging success (range 0-5, 19%= 5)	3.2 (135)	3.3 (31)	3.2 (19)

a (Walton, in prep.)
b Estimated 250 historical nesting territories in study area.
c Sample size.

TABLE 2. Annual cycle of prairie falcon activity in the Coast Ranges study area in California.

Month	Activity	
July through December	Wintering	Adult prairie falcons are uncommon in the Coast Range, the immature falcons are rare, adults are rarely at nesting territories.[a]
January through March	Wintering	Adults more common in Coast Range, adults occasionally at nesting territories, immatures very rare.[b]
March and April	Courtship	2 to 3 weeks.
March, April and May	Egg-laying	mean laying date 1972-1977 11 April (71)[c] mean laying date 1900-1960 4 April (209)[c]
April and May	Incubation	36-37 days[d], onset to pipping.
	Hatching	48-90 hours[d], pipping to hatch.
	Brooding	33-40 days[e], hatch to fledge.
May and June	Fledging	2-3 weeks of parental care after leaving nest.
June and July	Dispersal	Young leave the study area, adults move from nesting territories, females more common in flat open areas, males more common in rolling wooded areas.

a Most of the population may move to higher elevations outside of area.
b High juvenile mortality partially responsible for low numbers observed.
c Numbers in brackets represent number of recorded dates.
d Result of captive incubation of wild-collected eggs as part of this study.
e Variable depending on many factors including elevation, brood size and nest ledge size.

Manipulated Territories

This study was designed to further develop management techniques. As a result some techniques were tested using sub-optimal methods. If the optimum methods developed as a result of these tests had been utilized, the productivity of the manipulated territories would have been significantly higher. Even using sub-optimal methods in some tests, the fledging success of the 19 manipulated territories was increased by 21 percent (13 young). The additional young were produced from second clutches or released from captive breeding projects.

Three techniques were tested in this study: 1) double clutching, 2) clutch and brood augmentation, and 3) fostering (Table 3). Four topics of discussion pertaining to each of the techniques are presented: 1) a description of each technique, 2) a summary of its previous application, 3) the results of tests to further develop methods for application in California, and 4) the feasibility of each technique's application to California's raptor population, with emphasis on the peregrine falcon.

Double Clutching - This refers to the raptor management technique in which a biologist removes the first clutch of eggs and allows the wild raptor to lay and incubate a second clutch of eggs. Testing of this technique involves: 1) observation of a wild pair of prairie falcons to determine the onset of incubation, 2) removal of the completed clutch of eggs, which are immediately placed in a portable incubator for transport to the laboratory incubator, and 3) the adult pair "recycling" by laying a replacement clutch of eggs, which they incubate. This technique enables the number of fertile eggs per manipulated pair to be increased by approximately 67 to 100 percent per nesting season (Thelander, 1977). Some pairs may be unable to lay replacement clutches or some may lay smaller replacement clutches (Hickey, 1942).

Peregrine falcons lay replacement clutches, as do most other raptors in mid-latitude regions, if their eggs are removed or destroyed. Thelander (1977) reports on 307 clutches of peregrine falcon eggs collected by oologists in California. His analysis reveals that 99 of the 307 clutches were second clutches, 23 were third clutches, and one was a fourth clutch.

Cade (1974) describes the double clutching technique as a feasible method to increase wild peregrine falcon productivity. Fyfe (1976) describes the application of this technique by the Canadian Wildlife Service on peregrine falcons in Canada. This technique is also relied upon in captive breeding programs to increase captive falcon productivity (Cade et al., in press).

Success of the double clutching technique depends on several factors: 1) the stage in development at which eggs were collected, 2) the time of breeding season when clutch is laid, and 3) the individual variation of each breeding bird's ability to recycle.

In order to determine the optimum time for removal of eggs, thus insuring recycling, and to determine the period of time for recycling to occur, six prairie falcon nesting territories were tested (K-1, K-2, K-4, SB-1, SB-5, SLO-1). Eggs were removed from nests at various stages in incubation and during various periods in the breeding season (Table 3 and Table 4).

TABLE 3. Variation in the age of egg clutches taken and the techniques tested in the Coast Ranges study area in California, 1977.

Nesting Territory	Age Clutch Taken (days)	No. of Eggs	Technique Tested
K-3	3	4	Fostering
SB-5	14	5	Double Clutching
SLO-1	16	5	Double Clutching
K-1	18	5	Double Clutching
SB-3	23	3	Clutch Augmentation
SB-2	26	3	Fostering
K-2	26	4	Double Clutching
SB-1	32	5	Double Clutching
K-4	42	2	Double Clutching

* * *

Three of the prairie falcon pairs (K-1, SLO-1, SB-5) tested during the initial stages of incubation (1-18 days) recycled in 14 days. One pair (SB-1) that was being tested for success when double clutched during the later stages of incubation (19-37 days) recycled in 21 days; and two pairs (K-2, K-4) that were tested during the later stages of incubation failed to recycle (Table 4). When eggs are collected during the initial stages of incubation, recycling should occur in 14 days. When eggs are removed during the late stages of incubation, recycling may take longer or fail to occur. These results agree with the discussion by Green (1916). Figure 2 graphically illustrates the probability of recycling during different stages of incubation.

The pair at K-4 did not recycle after incubating their own addled eggs for 42 days. This is seven days longer than the normal incubation period of 36 to 37 days (Table 2). The pair at K-2 did not recycle after incubating their own eggs for 26 days. This clutch was collected after the mean egg-laying date for this area (Table 2). The pair at SB-1 did recycle after incubation of their own eggs for 32 days. This clutch was collected before the mean egg-laying date for this area. If eggs are collected during the late stages of incubation, but early in the breeding season, the probability of recycling may be greater than for pairs whose eggs are collected during the late stages of incubation and late period of the breeding season (Figure 2).

Based on the results from this study and from captive breeding programs, the optimum time for removal of the first clutch, to insure that prairie falcons will successfully recycle, is between the onset of incubation and 18 days of incubation. The incubation and hatching success of wild raptor eggs hatched in incubators when taken from nests at the onset of incubation has not been perfected. Best hatching successes occur when eggs have been incubated by captive or wild raptors for seven to fourteen days (Cade et al., in press). When eggs are moved between nests for augmentation of wild clutches, their early removal from the original wild nests will not be a factor in hatching success.

Using optimum methods, removal of eggs with 7 to 14 days of natural incubation and selection of pairs laying early in the breeding season, a large percentage of pairs could be expected to recycle and fledge young. The young from captively incubated eggs can then be used for augmentation of other wild nests. Double clutching at 14 days incubation will delay the eventual fledging of young from the wild nests by only 28 days.

TABLE 4. Comparison of data from double clutching tests in the Coast Ranges study area in California, 1977.

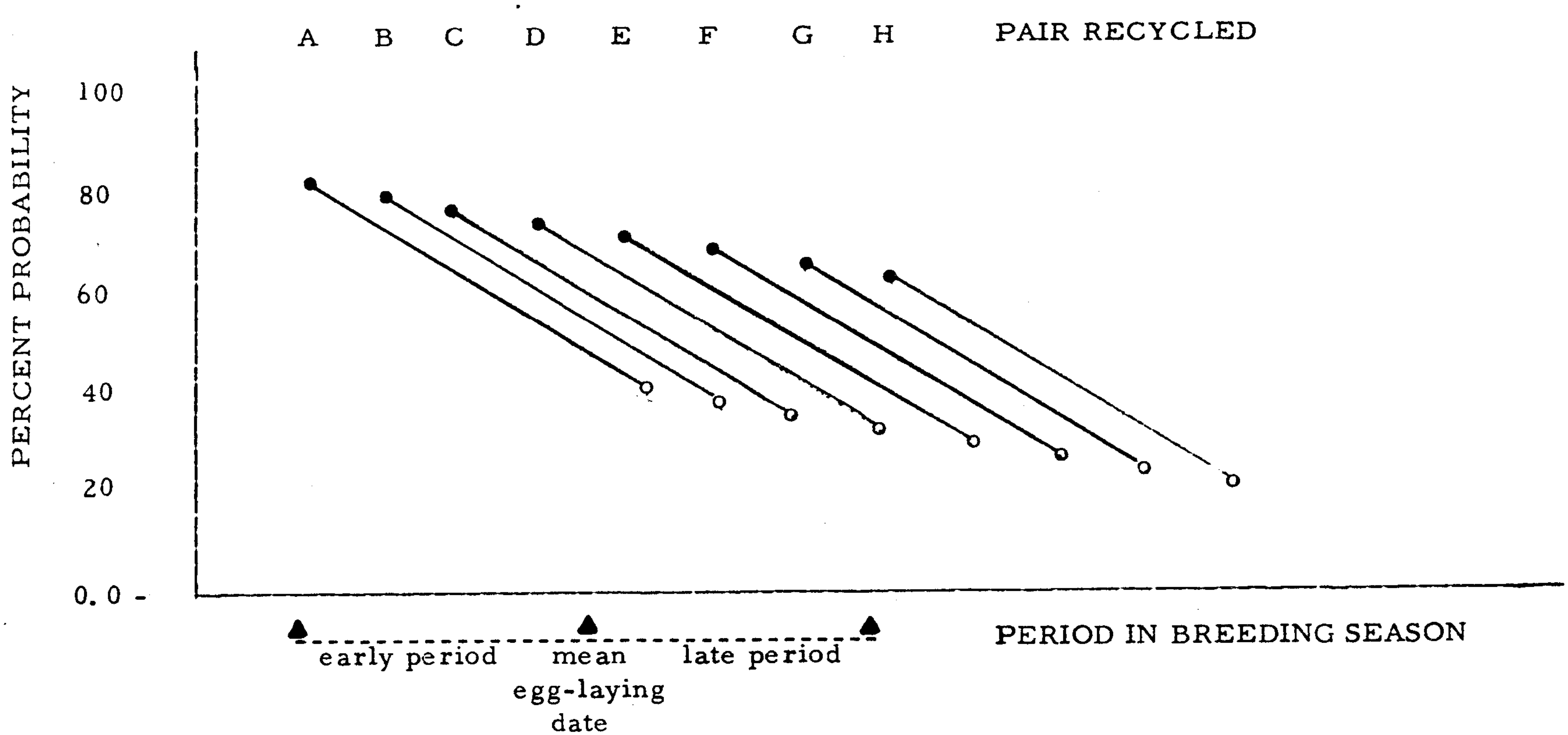
Nesting Territories	Date	Age Taken (days)	No. of Eggs Taken	No. Hatched	Date Second Clutch Completed	No. of Eggs (2nd set)	No. Hatched	Time Between Clutches (days)
SB-5	22 April	14	5	4	6 May	5	4	14
SLO-1	14 April	16	5	4	28 April	5	3	14
K-1	2 April	18	5	0	16 April	4	(2)[a]	14
K-2	25 April	26	4	3	no recycle	0	0	--
SB-1	7 April	32	5	5	28 April	5	0[b]	21
K-4	25 April	42	2	0	no recycle	0	0	--
			26	16 (62%)		19[c]	9 (47%)[c]	

a Although this was a second clutch, it was collected and incubated in the laboratory; one young died immediately after hatching under a captive falcon (see Table 1).

b No young fledged at this nest, due probably to predation since the nest was easily accessible.

c Since double clutching tests were conducted during various stages in incubation, productivity of the second clutches was decreased. If the double clutching tests were conducted at the optimum time, productivity of the second clutches would compare favorably with productivity of the first clutches.

FIGURE 2. Theoretical illustration of the probability of recycling of raptors nesting in mid-latitude regions.



A-H a sample illustration of incubation period (37 days) for eight pairs of raptors during various periods of the breeding season. Theoretically, these are eight lines in a continuous sequence of lines representing incubation periods for each clutch of eggs laid by pairs in a population.

- ● egg-laying date
- o hatching date
- —— incubation period

USE OF FIGURE: examples

<u>Pair A</u> -lays eggs during the early period of the breeding season;
high probability of recycling for early stages of incubation,
low probability of recycling for late stages of incubation.

<u>Pair H</u> -lays eggs during the late period of the breeding season;
medium probability of recycling for early stages of incubation,
very low pro[illegible]ility of recycling for late stages of incubation

Being located in the mid-latitudes, California has a long breeding season. Many raptors in these latitudes exhibit a wide range in egg-laying dates. The double clutching technique is readily applicable to the remnant peregrine falcon populations in California since the variation in egg-laying dates could enable early nesting pairs to recycle and fledge young no later than late nesting pairs in the population. Peregrine falcons and bald eagles within California have good and poor regions of productivity (Thelander, 1973, 1976). Double clutching can be used in those regions with many nesting territories having good productivity to provide additional young for augmentation in regions with nesting territories having poor productivity. Further research may enable utilization of this technique on the California condor population.

Augmentation - This refers to the raptor management technique in which a biologist adds eggs to clutches or young to broods in wild or captive raptor nests. To test this technique involves: 1) observation of a pair of raptors to determine the onset of incubation and egg hatching dates, 2) production, in captivity or wild nests, of eggs or young of synchronous age with those in nests to be augmented, and 3) addition of eggs or young to the wild clutch or brood. Productivity can be increased to maximize clutch or brood size in nesting territories in regions of poor productivity. At selected nesting territories, the productivity can also be successfully increased above the "normal" clutch or brood size.

In 1976 brood augmentation was tested for the first time in California. This test included the placement of two captive bred young into a wild nest in Modoc County which contained one wild prairie falcon (Walton, 1977). All three young successfully fledged. In recent years, The Peregrine Fund and the Colorado Division of Wildlife have augmented several peregrine falcon nests in the Rocky Mountains with young from captive breeding projects (Burnham, 1977). Fyfe (1976) reports on similar augmentation programs by the Canadian Wildlife Service. Spitzer (Zimmerman, 1976) placed osprey (Pandion haliaetus) eggs and young from Chesapeake Bay into nests on Long Island in order to augment the productivity of a declining osprey population.

The success of the augmentation technique depends upon: 1) the ability of the territory to support increased number of falcons in a season when nest is augmented, 2) the ability of the raptors to incubate and feed young during a season when their clutch or brood is augmented, and 3) the synchrony in development of the eggs or young when combined with the wild clutch of eggs or young.

This technique was further developed to determine: 1) at what stage of development of eggs or young can augmentation occur with the greatest degree of success, 2) what are the physical limits in terms of the number of young a pair of raptors can successfully fledge, and 3) the correct selection of nests for augmentation.

The technique of clutch augmentation was tested at two territories using slightly different methods. At SB-4, a clutch of three eggs was augmented by combining it with a clutch of three eggs from SB-3. At SB-3 the clutch of three eggs was removed and replaced with a clutch of five eggs from SB-5.

Prairie falcons commonly lay five eggs (Table 2). By using this technique, these 2 nests were augmented to normal or greater than normal clutch size. The pair at SB-5 recycled. Hence, SB-4 had 6 eggs, SB-3 had 5 eggs and SB-5 had 5 eggs.

The production of eggs at these three synchronous nesting territories had been increased from 11 to 16 eggs by augmentation and recycling. Fifteen of the 16 eggs hatched, one egg was addled in the second clutch at SB-5, 15 young fledged.

Brood augmentation was tested at five territories (K-5, M-2, SLO-4, SLO-5, SLO-6). Three young from captive breeding projects, four young from eggs collected in the recycling tests, and eight young that were moved between wild territories, were utilized for augmentation. Territories that had histories of good productivity were selected, except SLO-4 which had been unoccupied for at least ten years. The existing young at these territories were of synchronous age with young that were released. If young were released in nests where young were of an asynchronous age, the existing young were moved to adjacent nests with young of similar ages (Table 5).

Prairie falcons commonly have broods of five young (Table 2). By using the augmentation technique, these five nests were augmented to normal or greater than normal brood size. Two broods of seven young were formed as follows: 1) at K-5 three wild young were added to four existing young early in development, and 2) at SLO-6 three wild young were added to four existing young near fledging. At M-2 one brood of six young was formed when two wild young were added to a nest with four young early in development. Two broods of five young were formed as follows: 1) at SLO-5 three captively bred young were added to two existing wild young early in development, and 2) at SLO-4 four young from captively incubated eggs were added to one existing young near fledging age. Tables 5 and 6 show the exact age of young when brood augmentation occurred.

The number of fledglings at these five nesting territories had been increased from 15 to 30 by augmenting nests with young from several sources. All young fledged except for one in a brood of seven young at K-5 formed at an early age.

At one territory, M-3, two of the three young were removed for use in augmentation of a second territory. It was later determined that these two nests were not synchronous in age of the young, thus the two young were returned to their original nest (M-3).

Clutch and brood augmentation techniques were successful regardless of the stage in development of the eggs or young. All young regardless of age were readily accepted by adult prairie falcons. No nest abandonment by wild adult falcons occurred. SLO-4, which had no nesting activity for at least ten years, was augmented from one young to five young which all fledged. The generally excellent year in 1977 for prairie falcon productivity in the study area undoubtedly accounted for some of this success (Table 2).

A larger nesting territory sample size could be expected to show lower success for: 1) those nests which are augmented early in the development of eggs or young, and 2) those nests that are augmented to levels above normal clutch and brood size. Nests augmented to the number of a normal clutch or brood size can be expected to be successful, especially if they are manipulated at late stages in development of eggs or young.

Clutch and brood size augmentation is feasible for California's peregrine falcon and bald eagle populations. Augmentation is a simple technique that can be applied if captively bred or wild eggs and young are available. Augmentation does not increase productivity as quickly as the double clutching technique, but it can insure that all nests in the population fledge an optimum number of young per nesting season.

TABLE 5. Variation in the age of captive bred or captive incubated young and techniques tested regarding young released in the Coast Ranges study area in California, 1977.

Nesting Territories	Age Young Released Into Nests	Technique Tested	No. In Nest	No. Released Into Nest	No. Fledged
SLO-3	2	Simple Release[a]	3[b]	1[d]	1
SLO-5	8	Brood Augmentation	2	3[d]	5
SB-2	12	Fostering	0	2[d]	2
SLO-2	12	Simple Release[a]	3[b]	3[d]	3
K-3	13	Fostering	0	5[d]	5
M-1	21	Simple Release[a]	2[b]	1[c]	1
SLO-4	28	Brood Augmentation	1	3[d]	↓
SLO-4	33	Brood Augmentation	↑	1[d]	5
			3	19	22

a In simple releases, the young released became the brood. The existing young were moved to nests with young of synchronous age. If the young had been of synchronous age, then the release is brood augmentation and existing young remain as part of brood.

b Not included in totals since they were moved to other nests (Table 6).

c Captive bred.

d Captive incubated.

TABLE 6. Variation in age of wild prairie falcon young when moved between nests for brood augmentation tests in the Coast Ranges study area in California, 1977.

Original Nesting Territory	Age Moved (days)	No. of Young Moved	Final Nesting Territory	Original Brood Size	Augmented Brood Size	No. of Young Fledged
M-1[a]	13	2	M-2	4	6	6
SLO-3[b]	18	3	K-5	4	7	6
SLO-2[c]	30	3	SLO-6	4	7	7
		8		12	20	19

a 1 captive bred young was released to replace brood moved.

b 1 captive incubated young was released to replace brood moved.

c 3 captive incubated young were released to replace brood moved.

Fostering - This refers to the raptor management technique in which a biologist places young into the nest of a pair of raptors that has no young. The young and the wild adult pair are the same species. If young are placed in a nest of a different species of bird than the release is called cross-fostering. The test of this technique involves: 1) location of wild nests with infertile, broken, or unhatched eggs, 2) production in captivity, or location in the wild, of young that can be released at "foster" nests, and 3) release of foster young coinciding with the removal of broken or unhatched eggs. This technique can restore the productivity of a wild pair of raptors from zero, at nests that fail, to normal levels.

The Peregrine Fund and the Colorado Division of Wildlife have utilized the fostering technique at several peregrine falcon nests in the Rocky Mountains (Burnham, 1977). Young have been placed in the nests of different species by the Canadian Wildlife Service (Fyfe, 1976). Prairie falcons have been cross-fostered into ferruginous hawk (Buteo regalis), Swainson's hawk (B. swainsoni), and red-tailed hawk (B. jamaicensis) nests in Canada. Peregrine falcons have been cross-fostered by The Peregrine Fund into a prairie falcon nest in Idaho (Burnham, 1977).

The success of the fostering technique depends mainly on timing the release of young into nests that fail before the adult falcons abandon. In this population there were no nests that were failing so eggs that were collected when the foster young were released were hatched in laboratory incubators.

This technique was further developed by three methods; 1) a test at SB-2 was conducted to determine if foster young would be accepted after the incubation period had been expanded, 2) a test at K-3 was conducted to determine if foster young would be accepted after the adults had recycled, and 3) a cross-fostering test was conducted at SLO-1P by placing prairie falcons into a peregrine falcon nest that had failed. This test was designed to hold the peregrine falcons at the territory until young peregrine falcons could be obtained.

At SB-2 the eggs were replaced with "dummy eggs" after 26 days of natural incubation. The wild eggs were captively incubated and after hatching two 12 day old young were released at SB-2. This occurred after the pair had incubated for a total of 49 days. Both young fledged (Tables 3 and 5). At K-3, the pair had just completed a second clutch of 4 eggs and had incubated them for three days, when the eggs were removed and five 13 day old young were released (Table 5). All five young successfully fledged.

Even though neither pair of prairie falcons had hatched eggs, both pairs immediately accepted the foster young.

The pair of peregrine falcons at SLO-1P had failed to hatch their eggs (clutch size unknown) and the female was no longer attentive at the nest. One remaining unhatched peregrine falcon egg was removed and replaced with two nine day old prairie falcons. After nine days the prairie falcons were replaced by two 11 day old peregrine falcons that were produced by The Peregrine Fund. Later, the adult male peregrine falcon was illegally shot and eventually died. About the same time, one young peregrine falcon died of unknown causes. The adult female peregrine falcon was served food daily by a nest attendent until well after the remaining peregrine falcon fledged (Felton, 1977.). The two prairie falcons were released at SLO-4 and later fledged.

Both fostering and cross-fostering tests were successful. All foster and cross-foster young fledged except one peregrine falcon at SLO-1P.

Fostering peregrine falcon young into nests is feasible if captively bred young are available. Fostering young into peregrine falcon nests could also be accomplished by double clutching eggs and utilizing the captive incubated eggs as a source of foster young for nests that fail.

Many prairie falcons currently occupy historic peregrine falcon nesting territories in California (Thelander, 1977). Cross-fostering, using captively bred peregrine falcons placed in historical territories currently occupied by prairie falcons is feasible and may be advantageous in attempts to re-establish peregrine falcon nesting territories.

SUMMARY

Fifty-seven prairie falcon eggs were involved in testing three population manipulation techniques in this study: 11 eggs (3 clutches) were involved in manipulations between wild nests; 28 eggs (6 clutches) were collected from wild nests for incubation in the laboratory; and 18 eggs (4 clutches) were donated by captive raptor breeding projects for incubation in the laboratory (Table 7).

The 11 eggs that were moved between wild nests were fertile; 10 hatched and one egg was addled.

Twenty-three of 28 wild prairie falcon eggs collected for placement in the laboratory incubators were viable, five were broken or addled before they were collected. Five of the 23 viable eggs were overheated while being transported to the laboratory incubators. Shaking of eggs that occurred during transportation had no adverse affects. A total of 18 eggs collected from wild nests were incubated in the laboratory, 16 hatched and two were addled. Of these 16 young that hatched, one young died when less than a day old, and 15 others were released into wild nests.

Five of the 18 eggs donated from captive raptor breeding projects were fertile and viable. These five eggs hatched; four were released and one was returned to the captive raptor breeding project.

Sixty-one young prairie falcons fledged from the manipulated nesting territories. Nineteen of these young were released after they had been hatched in the laboratory (Table 7). Eight young were moved between wild nests and were not taken into the laboratory (Table 6). Thirty-four young hatched from second clutches or hatched from first clutches that were part of broods augmented or otherwise manipulated. As a result of the manipulations conducted, the productivity of the manipulated territories was increased by 21 percent.

TABLE 7. Summary of data regarding eggs manipulated in the Coast Ranges study area in California, 1977.

Nesting Territory	Date Manipulated	No. of Eggs	No. Fertile	No. Infertile	No. Addled	No. Hatched	No. Released
K-1	2 April	5	5	0	5[a]	0	0
SB-1	7 April	5	5	0	0	5	5
Lepori-1	7 April	4	0	4	0	0	0
Beeman	8 April	5	1	4	0	1	1
SLO-1	14 April	5	5	0	1[b]	4	4
Walton	16 April	4	0	4[c]	0	0	0
SB-3	22 April	3	3	0	0	3[h]	-
SB-4	22 April	3[i]	3	0	0	3[h]	-
SB-5	22 April	5	5	0	1	4[h]	-
Thelander	22 April	1	0	1	0	0	0
SB-2	24 April	3	3	0	1[b]	2	2
K-2	25 April	4	4	0	1[d]	3	3
K-4	25 April	2	2	0	2[e]	0	0
K-3	25 April	4	4[f]	0	2	2	1
Lepori-2	6 May	4	4	0	0	4	3[g]
Totals		57	44 (77%)	13 (23%)	13 (23%)	31 (54%)	19[j]

a All eggs overheated in transportation.
b Clutches containing one broken egg when collected.
c Placed in SB-2 for 23 days.
d Clutch contained one broken and one cracked egg when collected, cracked egg hatched.
e Both eggs addled when collected.
f Eggs collected as soon as laid; two eggs into incubator, one hatched, one addled
two eggs under captive falcon, one hatched and died, one addled.
g One young returned to captive breeding project.
h Eggs were moved to another nest, or eggs were added, no young released.
i Three eggs were added to this clutch from SB-3.
j 19 of 21 young that hatched in the laboratory were released (90%).

CONCLUSION

The techniques tested in this study have been used elsewhere in North America (Fyfe, 1976; Burnham, 1977). Each technique was tested in this study to develop optimum methods for application in California. Successful application of each technique was realized. As a result of this study, biologists can apply these techniques to raptor populations with greater success and promote greater productivity. Because the peregrine falcon is similar to the prairie falcon in its nesting natural history and ecology, the study techniques can be applied to the remnant population of peregrine falcons in California. It is feasible to adapt these techniques to other raptor populations with declining productivity, such as the southern bald eagle and the California condor.

ACKNOWLEDGMENTS

It is important to note that without a great deal of cooperation and the expertise of others, this study would not have been possible.

Robert Mallette of California Department of Fish and Game initiated the study and provided funding and direction through its completion. Howard Leach, Dutch Huckaby, and especially Hugh Thomas, also of the Department of Fish and Game, made valuable contributions.

Ron Walker was a constant field assistant and with his mountaineering abilities he assisted in the removal of eggs and the release of young at the nesting territories. He also assisted in the analysis of the techniques being tested. Carl Thelander and John Szabo assisted with the incubation and hatching of eggs and brooding of the prairie falcon young. Carl Thelander also provided editorial assistance and theoretical consultation. Frank Lepori provided a falcon puppet used for feeding the young during transportation. He also provided his pair of breeding prairie falcons for use in feeding and brooding the young hatched in the laboratory. Gary Beeman provided information on captive incubation. Carl Thelander, Gary Beeman, Frank Lepori, and Brian Walton provided eggs laid by captive breeding project prairie falcons. Young produced from eggs donated by Gary Beeman and Frank Lepori were released. Lloyd Kiff and Ray Quigley of the Western Foundation of Vertebrate Zoology, Los Angeles, California, provided historical information on prairie falcons from the Foundation collection and files.

The most essential contribution of field data to this study was gathered by observers at the nesting territories studied. The observers were S. Bowen, J. Edmisten, L. Hurst, J. Schmitt, L. Silva, L. Silveria, R. Walton, and C. Weaver.

Granite Stairway Mountaineering of San Luis Obispo, California, provided equipment and instruction; Eastman Kodak, Inc. of Palo Alto, California, provided many photographic services.

Appreciation and thanks are extended to the people of The Peregrine Fund of Cornell University, Ithaca, New York, and Fort Collins, Colorado, for their suggestions and information. Their efforts made this study feasible.

LITERATURE CITED

Burnham, William A. 1977. Progress report on peregrine management by The Peregrine Fund. 6 pp. ditto.

Cade, Tom J. 1960. Ecology of the peregrine and gyrfalcon populations in Alaska. University of California Publications in Zoology. 63(3):151-290.

__________, James D. Weaver, Joseph B. Platt, and William A. Burnham. 1977. The propagation of large falcons in captivity. Raptor Research News. 38 pp. in press.

__________. 1974. Plans for managing the survival of the peregrine con. pp. 89-104 in Proceedings of the Conference on Raptor Management Techniques. F. Hamerstrom Jr., B. Harrell, and R. Olendorff eds. Raptor Research Foundation. 145 pp.

Felton, Merlyn. 1977. Morro Rock peregrine falcon protection program, Morro Bay, California - 1977. Calif. Dept. of Fish & Game, Nongame Wildlife Investigations Report. 11 pp.

Fyfe, Richard. 1976. Rationale and success of the Canadian Wildlife Service Peregrine Breeding Project. Canadian Field Naturalist 90(3):308-319.

Green, C. de B. 1916. Note on the distribution and nesting habits of Falco peregrinus pealei Ridgeway. Ibis., ser. 10. 4(3):473-476.

Garrett, R. L. and D. Mitchell. 1973. A study of prairie falcon populations in Calif. Calif. Dept. of Fish & Game, Administrative Report No. 73-2.

Hickey, J. J. 1942. Eastern population of the duck hawk. Auk 59(2):176-204.

Leach, H. R., S. J. Nicola, J. M. Brode. 1976. At the Crossroads. Calif. Dept. of Fish & Game, report to the Governor of California.

Sprunt, A. 1969. Population trends of the bald eagle in North America in Peregrine Falcon Populations: their biology and decline. J. J. Hickey ed. Univ. of Wisconsin Press, Madison. pp. 347-351.

Thelander, C. G. 1973. Bald eagle reproduction in California 1972-1973. Calif. Dept. of Fish & Game, Administrative Report No. 73-5.

__________. 1976. Distribution and reproductive success of peregrine falcons (Falco peregrinus anatum) in California during 1975 and 1976. Calif. Dept. of Fish & Game, Administrative Report No. 76-3.

__________. 1977. The breeding status of peregrine falcons in California. Masters thesis. San Jose State University, San Jose, California.

Walton, B. J. 1977. Captive bred prairie falcon release. Journal of the California Hawking Club, 1976. pp. 54-55.

__________. in prep. Status of prairie falcon in Coast Ranges of California.

Wilbur, S. and L. Kiff. 1977. Eggshell thinning in Calif. condors. Condor, in press.

__________. in prep. California condor monograph. U.S.F.W.S. publication.

Zimmerman, David R. 1976. To save a bird in peril. Coward, McCann and Geoghegan, Inc. 286 pp.

GLOSSARY

Addled egg - refers to an egg which was inseminated but chick died in development stage.

Augmentation - a raptor management technique involving addition of eggs to clutches and young to broods; may be captive or wild.

Captive bred - refers to eggs or young produced by falcons held by permittees in captivity, no wild falcons involved in their production.

Captive incubated - refers to eggs and subsequent young that were produced by wild falcons but incubated in the laboratory in incubators.

Collected - taken from wild nest and placed in a laboratory (captivity).

Control - nonmanipulated nesting territories.

Cross-fostering - a raptor management technique involving placement of young of one species in the nests of different species.

Double clutching - a raptor management technique involving removal of the first completed clutch of eggs and allowing the wild raptors to lay a replacement clutch.

Early breeding season - refers to birds laying before the mean egg-laying date.

Early or initial stages of incubation - refers to onset of incubation to 18 days of incubation.

Fertile egg - refers to an inseminated egg and chick is developing.

Field - nonlaboratory; wild birds, nests, territories; Coast Ranges study area.

Fostering - a raptor management technique involving placement of young in nests of the same species but which no young are present, usually eggs are added when removed.

Further develop - to refine, elaborate, or expand methods or definition of, or test application of, raptor management techniques used elsewhere in North America.

Infertile egg - refers to an egg which was not inseminated and chick is not developing.

Laboratory - nonfield; transportation vehicles, incubation, hatching and brooding facilities, Frank Lepori's breeding chamber.

Late breeding season - refers to birds laying after mean egg-laying date.

Late or late stages of incubation - refers to days 19 to 37 of incubation.

Manipulation - to skillfully handle or control activities involving raptor management techniques.

Method - procedure by which a technique was conducted.

Moved - refers to transfer of young between wild nests.

Natural incubation - incubation of eggs by a wild raptor in the scrape where the wild raptor laid them; no manipulation.

Nesting territories - area defended by a breeding pair of raptors, includes the nesting location (cliff), and the nest (scrape on ledge, pothole, or crack in rock).

Nests - actual scrape on ledge of cliff, where eggs are collected or moved and where young are moved or released.

Optimum method - best or most favorable method or most defined, elaborated or expanded technique.

Population - refers to the group of raptors nesting in California or the Coast Ranges study area, not distinct or isolated from other raptors of the same species outside of these areas.

Recycle - activity of a pair of birds that has their first clutch of eggs collected; replacement clutch laying.

Released - refers to removal from laboratory (captivity) and placement in wild nests.

Replacement clutch - the clutch of eggs laid by a pair that recycles after its eggs have been collected.

Techniques - the systematic procedures by which raptor management is accomplished.

Territories - refers to nesting territories.

Tests - application of techniques in order to further develop methods or definitions of raptor management techniques.

Wild - nonlaboratory; field birds, nests, territories; Coast Ranges study area.

Young - refers to nestlings, fledglings, immatures; nonadult raptors.