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The Peregrine Falcons of Dinosaur National Monument, 1972–2004

Natural Resource Report NPS/DINO/NRR—2018/1782

ON THE COVER

Peregrine falcon (*Falco peregrinus*). U.S. Fish and Wildlife Service photo.

The Peregrine Falcons of Dinosaur National Monument, 1972–2004

Natural Resource Report NPS/DINO/NRR—2018/1782

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Contents

Figures v
Tables vii
Appendices ix
Executive Summary xi
Acknowledgements xiii

1 Introduction 1
- 1.1 Background 1
- 1.2 Recovery efforts in Dinosaur National Monument 1

2 Program Components 3
- 2.1 Nesting site inventories 3
- 2.2 Site occupancy monitoring 5
- 2.3 Productivity management 7
- 2.4 Productivity monitoring 14
- 2.5 Eggshell and pesticide monitoring 15
- 2.6 Natural history studies 25

3 Future Monitoring 29
- 3.1 Priority sites 29
- 3.2 Sampling 30
- 3.3 Survey frequency 30
- 3.4 Survey protocol 31
- 3.5 Whole egg and eggshell collection 31

4 Management Recommendations 33
- 4.1 Buffers and closures 33
- 4.2 Overflights 33
- 4.3 Closures 33
- 4.4 Illegal harvest 33

5 Conclusions 35

6 Literature Cited 37

Figures

Figure 2-1. Approximate distribution of peregrine falcon nesting territories in Dinosaur National Monument. 3

Figure 2-2. Occupancy of peregrine nest sites in Dinosaur National Monument, 1972–2004. 5

Figure 2-3. Field box that protected eggs during climbs from eyries 7

Figure 2-4. Example of portable incubator used to transport wild eggs from the eyries to The Peregrine Fund breeding facility. 7

Figure 2-5. Banding young prior to placement in a wild eyrie 8

Figure 2-6. HS tiercel in eyrie with three young during supplemental feeding effort. 11

Figure 2-7. Immature peregrine capturing tethered cotournix quail. 11

Figure 2-8. Hack box at Harding Hole. 12

Figure 2-9. Young peregrines in hack box. 12

Figure 2-10. Productivity (the number of fledged-age young produced at occupied sites with known outcomes) of peregrines in Dinosaur National Monument, 1972–2004. 14

Figure 2-11. Young fledged annually by known outcome pairs of peregrines in Dinosaur National Monument, 1972–2004 15

Figure 2-12. Annual productivity of peregrines in Colorado, 1972–2001 16

Figure 2-13. Thickness of first-clutch whole eggs collected in Dinosaur National Monument, 1976–1990 17

Figure 2-14. Thickness of first-clutch whole eggs collected statewide, 1970–2000 17

Figure 2-15. Thickness measurements of first-clutch eggs removed from SB, 1977–1990 18

Figure 2-16. Thickness measurements of first-clutch eggs removed from HS, 1978–1990. 18

Figure 2-17. DDE residue in contents of eggs collected in Dinosaur National Monument, 1976–1990 22

Figure 2-18. DDE residue in contents of eggs collected statewide, 1972–1990 22

Figure 2-19. Eggshell thickness compared to DDE in contents of whole eggs from Dinosaur National Monument 23

Figure 2-20. Eggshell thickness compared to DDE in contents of eggs collected statewide 23

Figure 2-21. Initiation dates of first clutches for Dinosaur National Monument peregrines, 1982–2004 26

Figure 2-22. Breeding sequence of Dinosaur National Monument peregrines. 27

Figure 2-23. Adult female perched at eyrie below climber. 27

Tables

Main Report

Table 2-1. New and total peregrine falcon nesting sites identified by year, Dinosaur NM, 1972–2004. 4

Table 2-2. Results of fostering efforts in Dinosaur National Monument, 1977–1989. 9

Table 2-3. Eggs produced from fostering and recycling efforts in Dinosaur National Monument, 1977–1990. 10

Table 2-4. Results of hacking efforts in Dinosaur National Monument, 1980–1988. 13

Table 2-5. Eggs obtained through recycling and fostering efforts, 1977–1990. 17

Table 2-6. Levels of pesticide residue and other compounds found in peregrine falcon eggs at Dinosaur National Monument, 1977–1990. 19

Table 2-7. Prey captured by peregrines at nest sites in Dinosaur National Monument, recovered (R) as prey remains in eyries (n=63) or observed (O) captured (n=23). 21

Table 3-1. Monitoring priority for Dinosaur National Monument sites. 29

Appendices

Table A-1. Occupancy of peregrine falcon sites in Dinosaur National Monument, 1972–2004. 42

Appendices

Appendix 1. Site Histories.....39
Appendix 2. Field Procedures.....43
Appendix 3. Methods of DDE Analysis and Eggshell Thickness Measurement 47
Appendix 4. Peregrine Monitoring Personnel, Dinosaur National Monument.....48

Executive Summary

The decline and recovery of the American peregrine falcon (*Falco peregrinus anatum*) is one of the most profound success stories in the history of American endangered species conservation. Dinosaur National Monument played a key role in that history. With the formation of the Rocky Mountain/Southwest Peregrine Falcon Recovery Team in 1974, Dinosaur National Monument became an integral part of the peregrine falcon recovery program. At that time, only eight of 22 Colorado nesting sites were occupied, one of which was in the monument. Inventories were expanded throughout the state and intense remedial actions were taken to sustain productivity. By the time peregrines were de-listed nationally in 1999, Colorado's population rested at 92 occupied sites with 14 residing in Dinosaur National Monument (NM). The recovery effort in Dinosaur NM was successful in large part due to the active and extended cooperation of the Colorado Division of Wildlife, National Park Service, The Peregrine Fund, Craig District of the Bureau of Land Management, U.S. Fish and Wildlife Service, and a host of contributed efforts. At the start of the recovery program, the northernmost breeding pair in Colorado occupied a territory at the confluence of the Green and Yampa rivers, near the center of the park. From 1977 through 1990, every eyrie that could be entered without undue risk to personnel was manipulated to facilitate each pair's breeding success. Thin-shelled eggs were replaced with plastic replicas and rushed to incubators at the Peregrine Fund. Then, captive, hatched chicks were returned and exchanged with the replicas, to be reared by each pair as their own. To augment captive production and provide additional young for release, pairs were recycled (induced to produce a second clutch of eggs), then treated as in the first case. Over the period of active management, 99 wild eggs were removed from Dinosaur NM eyries, 72 peregrine young were returned to these eyries, and 61 of these fledged successfully. An additional 30 young were released from hack sites (protective enclosures in which falcons are kept for several days before they are due to fledge); 20 of these successfully fledged. The eggs obtained in the course of foster efforts also provided information on shell thickness and pesticide residue trends for the pairs over 14 years. From one occupied territory in 1976, occupancy increased to an average of about 13 pairs at 16 known territories by 1991, when active management efforts were curtailed. The population has since continued to increase. Future monitoring protocols and protective measures are recommended.

Acknowledgements

More than any other endeavor with which we have been associated throughout our careers, the peregrine recovery program at Dinosaur National Monument has truly been a cooperative effort. The first monitoring effort was accomplished with one seasonal employee, jointly funded by the Colorado Division of Wildlife (CDW) and the National Park Service (NPS), using a vehicle provided by the Craig District of the Bureau of Land Management (BLM). The Peregrine Fund was intimately involved with incubating wild eggs and providing young for fostering and hacking efforts. Major TV network stations in Denver, Colorado, and Salt Lake City, Utah, provided helicopters to assist in the fostering program throughout the recovery program. The Colorado National Guard provided air support. Chevron, USA assisted in flying eggs and young peregrines to and from The Peregrine Fund's World Center for Birds of Prey in Boise, Idaho. Portions of the Colorado Division of Wildlife's efforts were intermittently funded through the Pittman-Robertson grant-in-aid program. Other CDW support came from the Great Outdoors Colorado initiative and private donations through Colorado's Wildlife Check-off.

This work could not have been accomplished without all those folks who became our eyes, ears, and scribes when we couldn't be in the field with them. Their names are listed in Appendix 4. But we would be remiss to not mention some very special people. Dan Berger (CDW), together with Jerry Craig, made virtually all the rappels into monument eyries to take wild eggs and place fostered birds. Jim Enderson (Colorado College) assisted with eyrie searches, inventories, and fostering efforts. He also piloted his Beechcraft to fly eggs to Boise and return young for fostering and hacking. Both Dan and Jim departed us in 2017, before publication, but they live on here. Glade Ross (NPS) and Kendall McDowell (BLM) participated in many inventory, monitoring, and fostering efforts. Mike Albee (BLM) and Bill White (U.S. Fish and Wildlife Service) provided valuable assistance and support. Joel and Drew Hogan were probably one of the few father/son combinations to work together for the National Park Service; they committed all hours of the day and night to the recovery effort. The full extent of their contributions may never be told.

This publication would not have been possible without Tamara Naumann, botanist for Dinosaur National Monument, who was always watching for peregrines, always ready to assist, carried on the monitoring program after our retirements, and provided the primary impetus for preparing this report. Thanks, Tamara, especially for listening to our stories and not chewing us out when we trampled through rare plants in the fostering efforts. And our thanks also to Peter Williams, who initially edited this manuscript. Several years passed and Tamara, assisted by Emily Spencer, picked up the dormant document, solicited peer reviews, and herded us and it toward publication. Jim Enderson, Skip Ambrose, and Dusty Perkins reviewed the manuscript and provided thoughtful criticism for improvement. We thank them for their time and effort. Then Tamara and Emily wisely enlisted Alice Wondrak Biel to edit and reassemble the work for publication. Alice caught those embarrassing errors that jaded minds missed. Who would have thought to double-check simple sums? Alice now probably knows more about peregrines than she ever wanted and we are better for her.

Finally, we need to thank our wives and children. Sally Craig and Donna Petersburg patiently supported all our long days and late nights. While all of our kids were involved to some extent, our daughters, Kelly (Craig) Rainford and Mylea (Petersburg) Bayless, spent two seasons as full-time volunteers on the peregrine falcon program in Dinosaur. They were a special treat for both of us.

1 Introduction

1.1 Background

The decline and recovery of the American peregrine falcon is one of the most profound success stories in the history of American endangered species conservation. Dinosaur National Monument played a key role in that history.

The peregrine falcon (*Falco peregrinus*) has the most extensive natural distribution of any bird in the world, limited only by high elevations, extreme heat, and extreme cold. It is found on all continents except Antarctica. The American peregrine falcon (*Falco peregrinus anatum*) breeds in Mexico, the United States, and Canada (USFWS 2013).

At one time, there were an estimated 3,875 nesting pairs of American peregrine falcons in North America. But the use of DDT as a pesticide during the 1940s–1960s resulted in a precipitous decline of these birds throughout most of their range. During this period, eggshell thinning and nesting failures were widespread in peregrine falcons. In some areas, successful reproduction virtually ceased (USFWS 2013).

Peregrines, which feed near the top of the food chain, suffered from the accumulation of DDE due to eating contaminated prey. DDE, a metabolite of DDT, prevents normal calcium deposition during eggshell formation, resulting in thin-shelled eggs that are susceptible to breakage during incubation (USFWS 2013). If an egg broke, then the contents contaminated adjacent eggs, as well as feathers of the adult. The tendency was then for the entire clutch to be abandoned, even if the remaining eggs were otherwise hatchable. If breakage occurred late in incubation, then the pair usually did not re-nest. Desiccation of whole eggs due to an abnormally rapid water loss through the thinned shell was another source of mortality.

By the time biologists realized the magnitude of the decline, the American peregrine falcon population was only about 12 percent of what it had been prior to the introduction of modern pesticides. In 1970, when they were placed on the endangered species list, the eastern population of the American peregrine falcon was gone and populations in the west had declined by as much as 90% below historical levels (USFWS 2013).

In 1972, the U.S. Environmental Protection Agency banned DDT, based on its adverse environmental effects (including to wildlife) and its potential risks to human health (USEPA 2017). That action, in combination with intense, coordinated recovery efforts, allowed the U.S. Fish and Wildlife Service to remove the species from the Federal list of threatened and endangered species in 1999. In 2013, there were 2,000–3,000 breeding pairs of American peregrine falcons in Canada, Mexico, and the United States (USFWS 2013).

1.2 Recovery efforts in Dinosaur National Monument

From 1973 to 1990, an unprecedented effort was mounted to monitor and recover dwindling peregrine falcon numbers throughout Colorado. Dinosaur National Monument (NM) was an important participant. The assistance of monument staff in monitoring and recovery efforts contributed substantially to the species' recovery in the region.

When the statewide population dwindled to only four known breeding pairs in 1976, one pair was in the monument, at a site officials named SB (see Figure 2-1). A second pair (at "HS") was discovered in 1977. Both of these sites were critical to the recovery program. Dinosaur NM aggressively monitored the falcons within and adjacent to its jurisdiction and cooperated with the U.S. Fish and Wildlife Service, Bureau of Land Management, and Colorado Division of Wildlife (CDW) to implement recovery actions that included manipulating breeding pairs to augment production and releasing captive young, hatched by The Peregrine Fund, at potential breeding cliffs.

Over three decades, sites were monitored annually for occupancy and productivity as the peregrines' nesting population expanded. When the U.S. Fish and Wildlife Service re-

moved the peregrine falcon from the List of Threatened and Endangered Wildlife (endangered species list) in 1999, 90 pairs nested throughout Colorado; 11 of these resided in the monument. By 2004, the monument's peregrine falcon population had expanded to 12 pairs, with three other pairs adjacent to its boundaries. This document reviews and summarizes the monument's peregrine recovery program from 1973 to 2004 and recommends future monitoring actions and protective measures.

1.2.1 Historical record

The earliest report of peregrine falcons in Dinosaur National Monument was a note by Park Naturalist J. Good, who observed one "Duck Hawk, Falco peregrinus anatum?" at a Yampa canyon site in April 1957. Clayton White reported to Gerald Craig that he had seen a pair of peregrines at the cliffs of the Gates of Lodore in the early 1960s. Although this site was observed almost annually after 1974, peregrines were not confirmed breeding there until 1989. An Echo Park site was reported to Craig in 1972 by Harold M. Webster, who had been informed of the site by bird watchers in the 1960s. Craig visited the site that same year and discovered a pair that had failed to produce young but were still courting. In 1974, a maintenance worker reported to Craig that he had seen peregrines nesting at Plug Hat Rock. He was familiar with peregrines when he lived in the eastern U.S. However, their presence was not confirmed at that time or in succeeding years. Prairie falcons (*Falco mexicanus*) nest along the escarpment and may have been mistaken for peregrines.

It is not surprising that more historical records of nesting peregrines are lacking for Dinosaur NM. Most human visitation within the region is restricted to the Yampa and Green river systems, rather than the remote canyon rims.

1.2.2 Study area

Habitats in Dinosaur NM have two outstanding characteristics with regard to peregrine falcons: (1) nearly continuous suitable nesting habitat along about 90 river miles, and (2) extremely varied elevations and habitats supporting a diverse avian (prey) fauna.

The monument is shaped somewhat like an inverted "T," with its boundaries roughly paralleling the Green and Yampa rivers. The Green River extends approximately 46 river miles from the entrance of the Canyon of Lodore to the mouth of Split Mountain Canyon. The Yampa River extends approximately 45 river miles from Deerlodge Park to the confluence with the Green River at Echo Park.

These river canyons form the core of peregrine falcon habitat within the monument. Green River canyons range up to 2,500 feet deep. Cliff heights along the Yampa River, especially on the south side, are commonly about 1,000 feet, with the greatest height being about 1,700 feet, near Warm Springs. Elevations at rim height range generally from 7,000 to 8,000 feet along the Green River; elevations at rim height along the Yampa River range from 6,000 to 7,000 feet. In many locations along the Yampa River, large fault blocks result in areas of lower elevation on the north side of the river.

Riparian communities dominated by boxelder (*Acer negundo*) and Fremont cottonwood (*Populus fremontii*) occur along both rivers. Such communities extend across enlarged floodplain areas at the mouths of side canyons along the Yampa and at the confluence of the rivers. Larger floodplain areas are not common along the Green River, except in Island Park and below Split Mountain Canyon. Canyon walls, where vegetated, are occupied by ponderosa pine, pinyon pine, Utah juniper, and some small stands of mixed conifer (ponderosa and Douglas-fir). Upland areas outside the canyons are generally dominated by sagebrush and pinyon/juniper communities.

2 Program Components

2.1 Nesting site inventories

In Europe, peregrine falcons have used the same nest sites since medieval times (Ratcliffe 1993). They were recorded at the same escarpments in the eastern United States for at least a century (Hickey and Anderson 1969). Although their recorded history of use in the Rocky Mountain region only spans about 150 years, peregrines have probably occupied the same nest sites for millennia. This tendency to use only certain cliffs over the years permits investigators to inventory and monitor population changes in an otherwise wide-ranging species.

Optimum nest cliffs for peregrine falcons exist throughout Dinosaur NM. From 1972 to 1983, investigators surveyed ideal cliffs that probably had harbored peregrines prior to the population decline but were vacant as a result of the decline. At the time, little was known of the peregrine's nesting population within the monument. In the early years, surveys of potential cliffs were conducted as resources permitted, but they were not systematic and visits were frequently too brief (i.e., observation periods were often less than the requisite four hours.)

Monitoring of peregrine breeding in Dinosaur NM was initiated upon discovery of falcons at SB in 1972 (Figure 2-1).[1,2] A second site at HS was reported in 1977, although it was probably occupied at the same time as SB. Apart from the cliffs at SB (and probably HS), which were continuously occupied, the

[1]Except for a hiatus from 1984 through 1986, peregrines have occupied the SB site annually for three decades. File notes record an observation of a fledgling in the area on July 7, 1985, and intermittent observations of adults in 1985 and 1986, suggesting the birds may have simply moved up the Green River, to an area not observed by monitors.

[2]Nest sites were named after the nearest prominent landmark and received a unique two-character alpha code. Sites in the Colorado portion of the monument also received statewide designations that were identical to the monument's codes, except for HR and SR. Due to conflicts with codes assigned elsewhere in the state, the Colorado Division of Wildlife changed HR to HS and SR to SB. In this report, HS and SB will be used for consistency with Craig and Enderson (2004). Park archives contain specific location information associated with site designations.

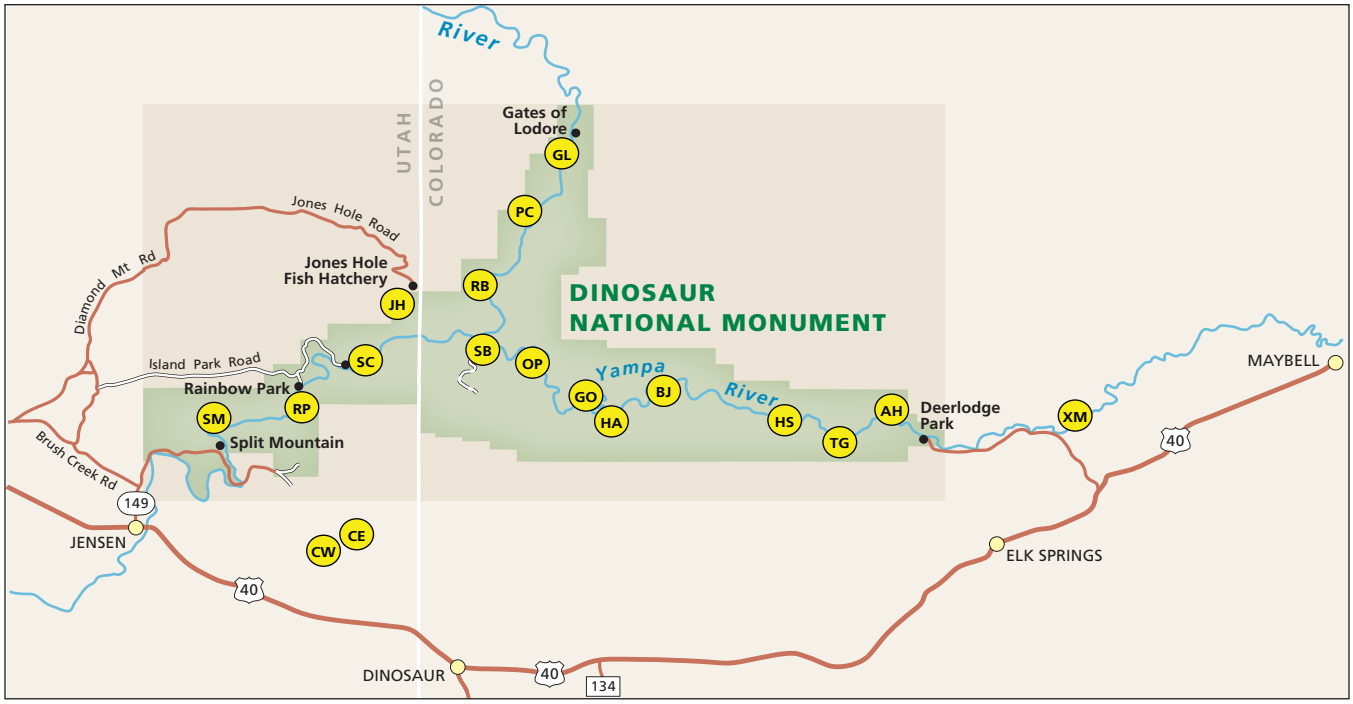


Figure 2-1. Approximate distribution of peregrine falcon nesting territories in Dinosaur National Monument.

Table 2-1. New and total peregrine falcon nesting sites identified by year, Dinosaur NM, 1972–2004.

Year	New site(s)	Total sites identified
1972	SB	1
1973	–	1
1974	–	1
1975	–	1
1976	–	1
1977	HS	2
1978	–	2
1979	–	2
1980	–	2
1981	–	2
1982	–	2
1983	–	2
1984	GO	3
1985	–	3
1986	–	3
1987	AH, XM	5
1988	OP	6
1989	BJ, GL, JH	9
1990	SM	10
1991	PC, RB	12
1992	–	12
1993	–	12
1994	RP, SC, TG	15
1995	–	15
1996	–	15
1997	–	15
1998	–	15
1999	–	15
2000	–	15
2001	CE	16
2002	–	16
2003	–	16
2004	CW, HA	18

inventories yielded no new pairs until 1984, when one new breeding pair was discovered at GO (Figure 2-1, Table 2-1, Appendix 1). River surveys in 1980 and 1981 were likely unsuccessful because the statewide population had ebbed to a low of only eight pairs (Craig and Enderson 2004). In 1984, the Rocky Mountain/Southwest Peregrine Falcon Recovery Plan directed that cooperating agencies throughout the Rocky Mountain region annually monitor nest site occupancy and reproduction (Craig 1984).

In 1989–1991, three to four teams of experienced observers were leap-frogged downriver in rafts to study potential nest cliffs. The first team pulled off at the first potential nest cliff on the river and observed for four hours while the other teams floated downstream to survey the next suitable cliffs. After four hours, the first team proceeded downstream, passing the other teams to begin monitoring the next available escarpment. This expanded the number of sites covered and permitted teams to devote up to four hours observing each cliff. In 1989, three sites (BJ, GL, and SC; Figure 2-1, Table 2-1) were confirmed using this technique, while large expanses of river canyon were surveyed and found to be vacant.

By 1994, 12 new territories had been added to the record since 1984 (Table 2-1). Survey teams had located nine sites in the course of their searches, and three pairs were confirmed from reports by other parties. Ten years later (in 2004), only three additional sites (CE, CW, and HA) had been recorded, all of which were found as the result of reports from employees and visitors. This failure to locate new pairs is probably a result of limited resources for inventorying potential cliffs, and not representative of the total pairs likely present.

In the course of this investigation, 18 nesting territories were discovered and monitored (see Figure 2-1, Table 2-1). As of this writing, additional searches had increased the number of total known territories to 20. Nest site occupancy is illustrated in Figure 2-2 and summarized in Appendix 1.

Initially, occupied nest sites were widely separated, with pairs occupying dominant

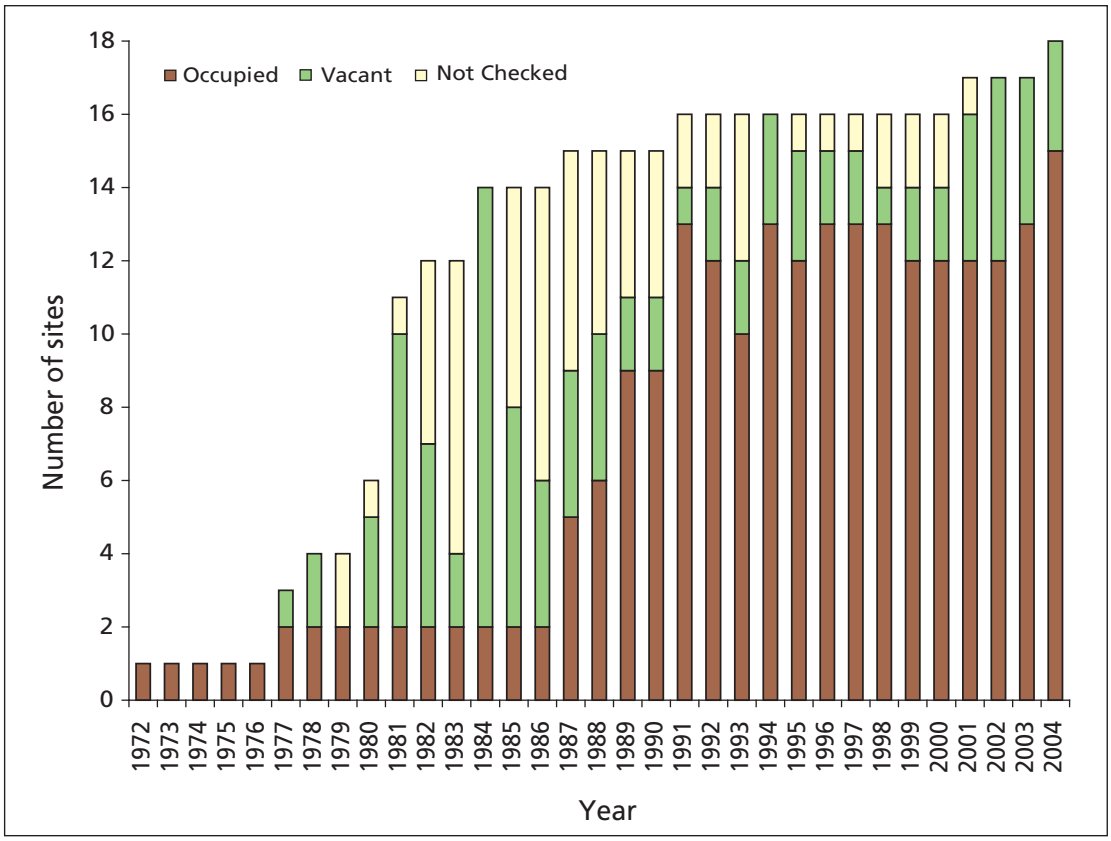


Figure 2-2. Occupancy of peregrine nest sites in Dinosaur National Monument, 1972–2004.

cliffs where the Green and Yampa rivers entered and exited the monument, as well as at their confluence. The distance between neighboring sites (n=14) averaged 4.0 miles, with a maximum separation of 6.9 miles and minimum of 2.0 miles. As intervening sites have been occupied, separation has reduced. In recent years, a pair at HA occupied a cliff only one half-mile from their neighbors at GO (see Figure 2-1). Although the one half-mile separation is recent, new pairs may be found between sites that are now 4–6 miles apart, if adequate cliffs are present.

2.2 Site occupancy monitoring

During the early years of the recovery effort, monitoring focused on the two known eyries at SB and HS. Observers would begin work in late March or early April to determine occupancy at the known territories. Courtship, ledge selection, egg laying, and incubation behaviors were closely observed and carefully documented. The primary intent of monitoring during the spring was to determine occupancy and confirm incubation (by observation of at least two eyrie exchanges) in support of the fostering program (see Section 2.3.1). Following eyrie manipulation activities, monitoring focused on continued incubation, young-rearing, and determining fledging success. Each known eyrie was typically observed at least twice a week, often for 2–3 consecutive days. Searches for new or additional eyries were conducted as time permitted.

By the early 1980s, the Colorado Department of Wildlife had established protocols for eyrie searches and monitoring (Appendix 2), and eyrie searches became more systematic. From 1984 through 1991, priority was given to key sites in the fostering program. Selected eyries were visited more often; other sites were visited only to determine occupancy, egg-laying, incubation, and fledging. After cessation of the fostering program in 1990, monitoring focused on determining occupancy and fledging success at all territories, with more intensive monitoring at selected territories to document eyrie-ledge selection, egg-laying, incubation, and young-rearing.

Monitoring was typically conducted by pairs of observers. At sites where observation was particularly difficult or critical questions remained about the peregrines' activities, additional employees and/or volunteers were used. Observing and recording peregrine activities, especially during incubation, is extremely difficult for a single observer unless the eyrie is close and readily visible. The typical monitoring effort, especially from courtship through incubation, involved locating a peregrine on the cliff or on the wing, then ensuring at least one of the monitors observed that bird continuously until interaction occurred with the second member of the pair. Failure to keep track of the initial bird often resulted in missing critical behaviors.

Monitors typically used high-quality binoculars and spotting scopes. In field notes, they recorded peregrine behavior, helmet sketches of individual peregrines, sketches (and photographs) of eyrie locations, weather conditions, and other avian species present. Field notes were later transcribed and stored in territory-specific notebooks. Summary reports were prepared annually.

Without prior knowledge of nest locations, it is impossible to establish a history of occupancy of Dinosaur NM sites. However, over the years, many potential nest cliffs were surveyed intermittently and found vacant. So it was possible to establish occupancy of some recently discovered sites from surveys in prior years, when the sites were checked and found vacant (Appendix 1).

A pattern of vacancy, then occupancy, emerges from these surveys. Prior to their confirmation, 12 sites (AH, BJ, GL, GO, HA, OP, PC, RB, RP, SM, TG, and XM) were monitored sufficiently to conclude that they were vacant at the time they were checked. All sites were subsequently occupied. Five of the sites (AH, BJ, GL, HA, and OP) received regular visits and the dates of occupancy were established. The other seven sites (GO, PC, RB, RP, SM, TG, and XM) were not visited annually, so the actual years of occupancy could have ranged from two to nine years since each site was last visited (Appendix 1). Indeed, casual reports from visitors suggest peregrines may have been present at some of these sites for several years before such occupancies were confirmed. Shortage of staff time often precluded systematic follow-up on the casual reports.

Protection from predators, a moderated microclimate, and suitable substrate must be present for peregrines to consider a ledge for occupancy. The number of nest ledges documented within breeding territories generally increased over time as pairs relocated to previously unknown ledges. We examined ledge use at six sites with the longest history of occupancy (AH, BJ, GL, GO, HS and SB, totaling 101 nest years). Forty percent of the ledges were used in more than one year. Two ledges were reused on six occasions, 3 on four occasions, 3 on three occasions, 13 ledges were reoccupied twice, and 42 ledges were used once. The greatest separation of nest ledges within a territory varied from 0.9 miles at BJ to 1.19 miles at SB, and averaged 0.57 miles for all territories. This suggests that although observers should examine previous ledges, nest searches should include all probable ledges on cliffs in the vicinity.

Territory vacancy may be difficult to establish where habitat is almost continuous, as in the river corridors of Dinosaur NM. If peregrine falcons relocate to an alternate cliff and are not discovered, then the territory may be erroneously designated as vacant. This may have been the case at OP when the traditional nest cliffs were abandoned in 2001 and 2002, although single peregrines were seen passing through the area. In 2003 and 2004, the pair was discovered 0.5 miles downstream, around a major bend in the Yampa River canyon.

This also occurred in 1991, at a site initially designated MR, when an adult pair with a flying juvenile was reported but the site was regarded as vacant in subsequent years. In 1994, an adult pair of peregrines with three fledglings was found at SC, about 1.3 miles away, across the Green River. At the time, two sites (MR and SC) were on record. However, as years passed, SC continued to be occupied after MR was abandoned. Because the cliffs were never occupied concurrently, we assumed both cliffs fell within a single pair's territory. The separation of cliff faces at MR and SC is greater than the statewide average of 0.7 miles, but well within the maximum of 2.1 miles of separation of nest ledges observed at

territories elsewhere in Colorado (Craig and Enderson 2004). MR was combined with SC and deleted for this report.

Similarly, the SB territory was regarded as vacant from 1984 through 1986, although adult birds were occasionally observed and a fledgling was seen in at least one year. If a nest cliff becomes vacant, potential cliffs within at least 1.5 miles should be carefully examined to ensure the pair has not relocated. Otherwise, investigators may erroneously conclude the territory was abandoned.

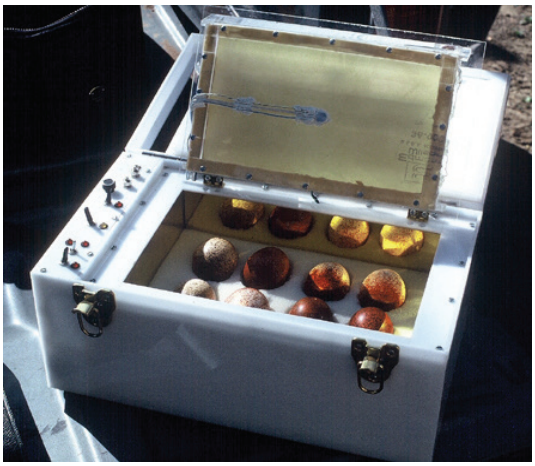
COLORADO DIVISION OF WILDLIFE/G. CRAIG

Figure 2-3. Field box that protected eggs during climbs from eyries. Four wild eggs are in the box; the item at the left is a casting that was collected to analyze prey remains.

2.3 Productivity management

2.3.1 Fostering

In 1974, the CDW entered into a partnership with The Peregrine Fund to establish a captive propagation facility at the division's Wildlife Research Station in Fort Collins, Colorado. In addition to propagating and rearing captive falcons, The Peregrine Fund also agreed to incubate and hatch eggs from the wild. This permitted the CDW to develop the technique of replacing thin-shelled eggs of wild peregrines with artificial eggs and, near the end of the normal incubation period, with captive-hatched young. The technique was successful and fostering became an important tool for recovering and sustaining the population.



CDW/G. CRAIG

Figure 2-4. Example of portable incubator used to transport wild eggs from the eyries to The Peregrine Fund breeding facility.

2.3.1.2 Methods and techniques

A critical component of the fostering program was monitoring to determine the onset of egg-laying and incubation. Five to seven days of natural incubation resulted in optimal survival of eggs in the breeding facility. During that 5–7 day window (some eyrie manipulations occurred outside this window, with natural incubation ranging from 0 to nearly 20 days), climbers would rappel into an eyrie, place the wild eggs in a specially constructed egg box (Figure 2-3), replace the wild eggs with a similar number of artificial eggs, and ascend to the canyon rim. The wild eggs were then placed into a portable incubator (Figure 2-4) and transported to The Peregrine Fund breeding facility (initially in Fort Collins, Colorado; later in Boise, Idaho). There, the eggs were measured and weighed, then assigned an incubation regimen. Cracked eggs were glued with Elmer's glue and humidity was regulated to compensate for water loss. Given the extraordinary incubation conditions some eggs required, it is estimated that approximately half of the wild eggs brought in for artificial incubation probably would not have hatched in the wild.

Single, unhatched eggs were observed among broods of week-old chicks on several occasions. Based on experiences at The Peregrine Fund's incubation facilities, eggs with less than 10–12% thinning were usually regarded as hatchable in the wild. If thinning ranged from 13 to 18%, then the possibility of hatching under natural incubation was possible but not likely. If shell thinning exceeded 18%, then the eggs were considered unhatchable in the wild.

Monitors regularly observed manipulated eyries to confirm continued incubation of the artificial clutch. Without exception, in all fostering attempts in Dinosaur NM, the adult

peregrines continued incubating the artificial eggs. Near the end of the normal incubation period (out of concern that the adult peregrines might abandon if artificial eggs remained too long), CDW climbers would return with captive-hatched peregrine chicks. Nestlings, 18–21 days old, were preferred, because they were large enough to band and could endure the travel and handling. Upon arriving at the cliff rim, the young were banded (Figure 2-5) and placed in a two-tiered wicker basket fitted with backpack straps. The climber then rappelled into the eyrie and replaced the artificial eggs with 2–4 young peregrines.

NATIONAL PARK SERVICE

Figure 2-5. Banding young prior to placement in a wild eyrie.

Several dead coturnix quail (*Coturnix corturnix*) were usually left scattered along the eyrie ledge. During the rappel, the adult peregrines were usually very agitated, vocalizing and stooping near the climber. Almost immediately after the climber was off the ledge, and upon removal of the rappelling rope from the front of the eyrie, the adult falcon (female) would return and attempt to brood the young.[1] In the meantime, the tiercel (male) would usually remove the dead quail from the eyrie ledge and cache them in other locations on the cliff. Usually within 10 minutes, the falcon would respond to the hungry, vigorously begging young (which were not fed before being placed in the eyrie) and cease attempting to brood them. Typically, the falcon would then move near the eyrie edge and wail (food solicitation). The tiercel would then retrieve dead quail and deliver them to the eyrie. When the falcon began feeding the young, the adoption was judged successful. Peregrines failed to adopt the young in only 1 of 22 fostering attempts in Dinosaur NM. In that instance, the adult at XM, in 1988, had apparently been lost and only the tiercel was on the territory when the young were placed in the eyrie. These young were retrieved and distributed among other eyries.

Two variations of fostering were also employed at Dinosaur NM. The first was "recycling," a method designed to increase the number of eggs available from wild sites. Recycling involves removing the first clutch of eggs to stimulate the pair to produce a second clutch, which would then be replaced with either artificial eggs or captive-produced young. On a few occasions late in the recovery effort, second clutches were left in the eyrie to be incubated naturally. (See a full discussion of this technique in Recycling, Section 2.3.2.)

The second variation was to temporarily place young prairie falcons in an eyrie if appropriately aged peregrine young were not available. In 1978, appropriately aged peregrine young were not available near the end of the natural incubation periods for fostering at the SB and HS eyries. The SB eyrie (with artificial eggs) was found abandoned on May 25, perhaps due to a prolonged, severe storm that occurred about a week earlier (field notes indicate several prairie falcon eyries in Colorado and Wyoming were also abandoned during the storm). Four young prairie falcons were placed in the HS eyrie on that same date; they were replaced with peregrine young on June 13. In 1979, the HS eyrie was recycled and received captive-hatched peregrines. However, appropriately aged peregrine young were not available for SB. Two young prairie falcons were placed in the SB eyrie on May 20 and replaced with peregrine young on June 6. In both years, the prairie falcon young were returned to their original eyries. In 1981, three captive-produced prairie-falcon young were placed in the HS eyrie for only four days prior to replacement with peregrine eyasses (young).

[1]In traditional terminology, the female falcon is referred to as the "adult," or simply, "the falcon." The male, which tends to be 1/3 smaller than the female, is called the "tiercel."

2.3.1.3 Results

Fostering boosted productivity at a time when it was critical to maintain the population. Between 1974 and 1989, a total of 229 fostered young were placed in 69 eyries throughout Colorado. Dinosaur NM received 72 of these young, which were fostered in 21 attempts from 1977 through 1989 (Table 2-2). Until 1984, only two known sites (HS and SB) were occupied and provided the opportunity to greatly boost productivity. During 1974–1983, only two wild young were produced in five breeding attempts (0.40 young/pair). However, 25 more young were fostered in 10 other attempts (2.50 young/pair). From 1984 through 1989, 33 young were fostered in 11 attempts (3.00 young/pair), while eight wild pairs produced 12 young (1.50 young/pair).

Fostering efforts were initiated but discontinued in Dinosaur NM on two occasions. In 1978, the pair at SB incubated four eggs that were replaced with replicas, but the pair abandoned the nest before captive-hatched eyasses (unfledged nestlings) were returned. The pair at XM was recycled in 1988. When observers returned to remove the second clutch of eggs, there were only two eggs. One of those eggs had what appeared to be egg contents on its surface, suggesting there may have been at least one additional egg in the eyrie. The two eggs were replaced with captive-produced eyasses. However, the adult falcon was missing and the tiercel displayed no interest in the young. Because the second clutch of eggs was warm when we entered the eyrie, it was postulated that the falcon had been lost in the previous 24 hours and the tiercel had continued to incubate. After several hours in the eyrie, the eyasses were removed and distributed among young fostered at HS and SB.

Loss of all fostered young occurred twice. The first foster experiment in Dinosaur NM was undertaken at SB in 1977. Prior to that, the site failed to produce young. The falcon disappeared in 1976 and the tiercel attracted a new mate in 1977. That year, the pair was fostered to avoid probable failure. The clutch of two recently laid eggs was replaced with replicas. Two captive-hatched young were later exchanged for the replicas and a third infertile egg that the pair had laid. Although initially accepted by the adults, it appeared the eyasses were abandoned several weeks later, but prior to fledging. The falcon displayed aberrant behavior during the interval.

The second foster attempt failure occurred at SB in 1982. Four wild eggs were replaced with four replicas. When four captive-hatched young were returned, only two replicas remained. The young were adopted by the pair, but by the anticipated date of fledging, all young had disappeared and a single adult was only seen briefly defending against a golden eagle (*Aquila chrysaetos*). Golden-eagle predation was speculated, because a pair of eagles nested within 0.8 miles of the peregrine eyrie and an eagle was observed killing a fledgling the previous year. Loss of all young—and possibly an adult—to eagles is exceptional.

Possible insecticide poisoning was also considered. The U.S. Department of Agriculture Animal and Plant Health Inspection Service sprayed multiple applications of Sevin 4 Oil (carbaryl) for Mormon cricket (*Anabrus simplex*) control within four miles of the nest cliff. Ingestion of contaminated prey items from the

Table 2-2. Results of fostering efforts in Dinosaur National Monument, 1977–1989.

Site	Young placed/Young fledged													
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
GO	–	–	–	–	–	–	–	–	4/4	–	4/4	3/2	–	11/10
HS	–	4/4	4/4	–	4/3	–	4/4	4/4	4/4	2/2	3/2	4/4	–	33/31
SB	2/0	0/0*	3/3	4/4	4/3	4/0	–	–	–	–	3/3	5/3	3/3	28/21
XM	–	–	–	–	–	–	–	–	–	–	–	0/0*	–	0/0*
Total	2/0	4/0	7/7	4/4	8/6	4/0	4/4	4/4	8/8	2/2	10/9	12/9	3/3	72/61
Attempts	1	2	2	1	2	1	1	1	2	0	3	4	1	21

*foster attempt aborted; pair abandoned nest before young were returned.

treated areas or direct contact with sprayed vegetation may have disrupted brain cholinesterase functions in the peregrines and made them more vulnerable to predation themselves.

2.3.2 Recycling

Recycling is the technique of visiting nests within 10 days of initiation of incubation and removing the clutch without replacing the eggs. Invariably, 14 days after the eggs are removed from the eyrie, the pair has relocated to another ledge and begins to lay a second clutch of eggs. However, likelihood of failing to lay a second clutch increases daily when the pair has already incubated 10 days. Hence, it is critical to know when incubation commenced so that the eggs can be removed within 10 days. All eggs removed through recycling were placed in portable incubators and transported to The Peregrine Fund's facilities for incubation. Aside from the obvious advantage of increasing wild production of eggs, recycling was used to delay pairs until captive-produced young were available. In rare cases when a ledge was exposed to the elements or accessible to terrestrial predators, the falcons were induced to relocate to a (hopefully) more secure site.

In 1979, the pair at HS was recycled to delay them until captive-hatched young of an appropriate age were available. The pair produced three eggs in each of the first and second clutches and four captive-hatched young were returned to them. Poor productivity among captive breeders at The Peregrine Fund's facility in 1986 necessitated recycling several Colorado sites to provide young for placement in the wild. HS once again provided four eggs from the first clutch and three eggs from the second clutch. They received two peregrines eyasses to rear.

By 1988, increased demand from other states for captive-produced falcons reduced the availability of falcons required to meet recovery goals for Colorado. From 1988 through 1990, pairs were recycled eight times, with 37 eggs taken into captivity to be hatched and returned to the wild in Colorado. Young were fostered back to pairs in four cases and pairs were permitted to keep and hatch their second clutches in four other cases (Table 2-3). All of the young placed in hack boxes (see Section 2.3.4) on tall buildings in downtown Denver from 1988 through 1990 were produced from eggs taken in the monument. The remaining young were distributed to hack sites on Colorado's Front Range.

2.3.3 Prey supplementation

In 1981, one of the adults at HS was lost during young-rearing. This prompted an attempt to supplement prey to the remaining adult. If successful, it would ensure adequate food and permit the tiercel to remain in the immediate vicinity to defend against predators.

The eyrie was positioned just below the cliff rim and immediately below a popular river overlook. During egg-laying and early incubation, observers noted that even the closing of a vehicle door in the parking area was sufficient disturbance to flush an adult from the eyrie. To limit disturbance of the peregrines, the entrance road and overlook area were formally closed to public use on May 7. On May 13, four wild eggs were replaced with artificial eggs. Because of concerns about unauthorized entry to the area and subsequent disturbance of the incubating peregrines, the Colorado Division of Wildlife and Dinosaur

Table 2-3. Eggs produced from fostering and recycling efforts in Dinosaur National Monument, 1977–1990.

Site	Eggs in 1st clutch, Eggs in 2nd clutch														
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Eggs taken
GO	–	–	–	–	–	–	–	–	3	–	4	3,3	4,1+*	–	17
HS	–	3	3,3	–	4	–	4	3	4	4,3	4	2	–	2,2*	39
SB	3	4	3	4	4	4	–	–	–	–	4	4,3	4,3	3,3+*	43
XM	–	–	–	–	–	–	–	–	–	–	–	4,2*	–	2*	4
Total	3	7	6,3	4	8	4	4	3	7	4,3	12	13,8	8,4+	7,7+	103

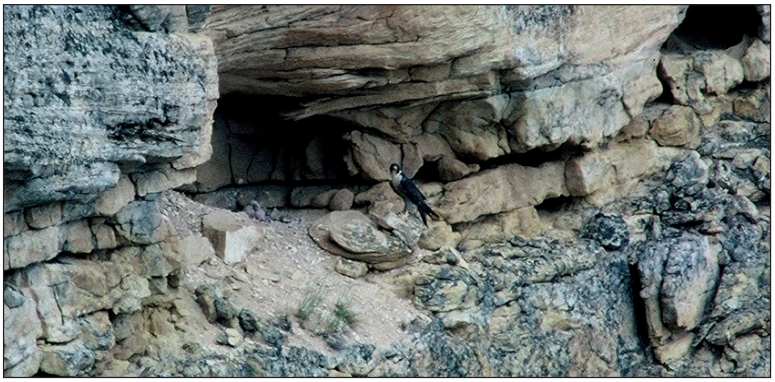
*not fostered

NM stationed observers at the cliff from June 5 through sometime after fledging. On June 5, the peregrine pair received three 5-day-old prairie falcons.

On June 8, four peregrine young (about two weeks old) were placed in the eyrie. These young were banded in the eyrie four days later. Monitoring by CDW and Dinosaur NM monitors confirmed continued presence of all six birds. At about 0300 hours on June 25, observers heard a commotion at the cliff, including peregrine distress calls and great horned owl (*Bubo virginianus*) vocalizations. Observers had heard great horned owls calling during previous evenings, as well. When checked at first light, only three eyasses were sighted. Later in the morning, the fourth nestling, apparently injured, was observed on a ledge some 150–200 feet below the eyrie; this young was reported to be dead the next day. While the tiercel was observed, there were no sightings of the adult falcon. The female was apparently attacked and killed by a great horned owl during the night (owl feathers were later located in the eyrie).

Over the next several days, the adult male continued to feed all three remaining eyasses, though at least one seemed to be less robust than would normally be expected. The tiercel was markedly less aggressive in defense of the territory (both toward humans and other raptors). After consultation with staff from CDW (Jerry Craig) and The Peregrine Fund (Bill Burnham), the consensus was that the single adult could probably rear one young successfully to independence, but not all three. Burnham suggested trying to offer pigeons to the adult. On June 30, Steve Petersburg and Joel Hogan (Dinosaur NM) tethered a pigeon (*Columba livia*) on the cliff rim. Within 15 minutes the adult killed the pigeon but was unable to break the tether. Hogan broke the tether and left the second pigeon in the same area. The adult returned within five minutes for both pigeons. Observers reported that all three young had full crops that evening. The next day, Hogan and Dan Berger (CDW) returned with several coturnix quail and pigeons, which the male later killed at the same tether location. Two days later, volunteers arrived with some 200 coturnix quail from The Peregrine Fund. Each day, the male removed 4–7 live and dead quail and flew directly to the eyrie with them (Figure 2-6).

After the young fledged, and for the next five weeks, 4–6 quail were presented daily (Figure 2-7). Initially, all were taken by the adult—but as the young became proficient, they took their own quail. Although quail were the bulk of their diet, the tiercel was also observed with wild prey. Throughout this period, the tiercel vigorously defended against several golden eagle intrusions, as well as against red-tailed hawks (*Buteo jamiacensis*) and turkey vultures (*Cathartes aurus*). All three young achieved independence. Although labor-intensive, supplemental feeding probably ensured a single adult could rear three young.

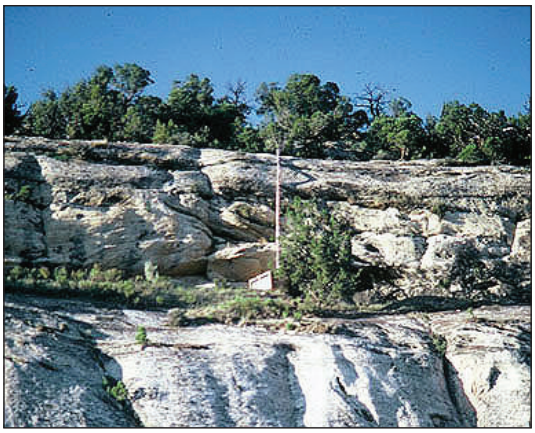


NPS/G. WOLFE

Figure 2-6. HS tiercel in eyrie with three young during supplemental feeding effort.

NPS/G. WOLFE

Figure 2-7. Immature peregrine capturing tethered cotournix quail.



NPS/S. PETERSBURG

Figure 2-8. Hack box at Harding Hole.

CDW/G. CRAIG

Figure 2-9. Young peregrines in hack box.

2.3.4 Hacking

Hacking is a method adopted from falconry, in which nestling falcons are confined in an enclosure several days before they are due to fledge. In the interval, they imprint on their surroundings and will return to the hack box for food and shelter after release. Before they are independent, the falconer catches the young and trains them.

For the recovery program, hacking of peregrines was modified: the young falcons were not trapped back for training, but were to become independent. The hack box was placed on a cliff ledge in the midst of suitable habitat. The intent was that, with average mortality, a pair of hacked peregrines would eventually establish a territory near the hack box.

Hack boxes (Figures 2-8 and 2-9) were carried to cliff tops and placed on secure ledges. Young peregrines, 34–35 days of age (range 32–37 days), were placed in the hack box and fed by attendants. To prevent the young peregrines from imprinting on humans, the attendants remained out of sight. The hack box was opened when the young peregrines were 42–43 days old (range 41–44 days). As the peregrines fledged, they usually returned to the hack box within a day to feed. Attendants camped nearby, fed the young, and observed the site throughout the daylight hours until the young had dispersed from the area.

Three consecutive years of releases from the same site are generally considered sufficient to provide an adult pair. For a complete description of hacking peregrines, see Sherrod and others (1987). The method was used to re-establish extirpated falcons throughout the eastern United States, Idaho, Montana, Utah, Wyoming, and Canada. Sixty-four hacking attempts occurred in Colorado (Craig and Enderson 2004). Eight were operated in Dinosaur NM.

Hacking augmented the minimal wild production of the monument's two remaining pairs during the early 1980s. Harding Hole was selected for the first hack site in 1980. Four young were placed in the hack box, but attendants heard great horned owl vocalizations nearby. Because owls will kill recently released falcons when given the opportunity,

the release was cancelled. The young were distributed to another hack site. Results of the hacking program are summarized in Table 2-4.

A second hack site was operated at Deerlodge Park from 1982 through 1984. Of 14 young received at that site, only six successfully reached independence. During the first year, a pair of yearling peregrines frequented the site after the young were released. The hacked young begged from the yearlings on several occasions. About two weeks after the box was opened, a day-long storm occurred and all the birds disappeared. The hacked young may have been lured away by the older birds. In 1984, two (confirmed) and possibly three of the five young were killed by golden eagles shortly after release. Because of possible future eagle attacks, the site was then closed.

A third hack box at Split Mountain was used from 1984 through 1988 (1984, 1986–1988). This site experienced the greatest success rate (88%), with 14 of 16 released young reaching independence.

Predation by golden eagles and great horned owls resulted in termination or cancellation of hack attempts in Dinosaur NM and elsewhere (Craig and Enderson 2004; Sherrod et al. 1987). In 1982, the peregrines released from the Deerlodge Park hack site roosted in the cottonwood gallery forest near the public campground upstream from the hack site prior to their disappearance after the storm. Because this riparian forest habitat contained several great horned owls, The Peregrine Fund was concerned about possible predation on released peregrines. After attempts to trap the owls failed, several were lethally removed under the authority of Peregrine Fund permits. The Peregrine Fund stipulated that owls would need to be removed from the roost areas before any peregrines would be released in subsequent years.

In 1983 and 1984, with requisite federal and state permits, monument staff removed owls from the campground area over a period of 3–4 nights prior to opening the hack box. However, the owl territories generally remained vacant for only about 10–14 days before reoccupation. As noted above, no further releases of peregrines were made at Deerlodge Park. Hacking operations were shifted to the Split Mountain hack site.

2.3.5 Experimental release of adults

In the course of release efforts elsewhere, some young peregrines suffered accidents and had to be brought back into captivity. Subsequent efforts to return them to the wild were generally unsuccessful. The Peregrine Fund obtained permission from the U.S. Fish and Wildlife Service (USFWS) to hold several pairs of the falcons and train them to hunt together so that one or both could be released into a vacant territory as adults. The Fund requested they be alerted if any sites in Colorado were occupied by single adults so the experiment could proceed.

Early in the 1981 breeding season, observations at HS indicated that only an adult falcon was present. The Peregrine Fund was invited to release a trained tiercel at the site. A conditioned adult male was transported to

Table 2-4. Results of hacking efforts in Dinosaur National Monument, 1980–1988.

Site	Young placed in hack box/Young achieving independence										
	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total	Success
Harding Hole	0/0*	–	–	–	–	–	–	–	–	0/0	0%
Deer Lodge	–	–	5/0	4/4	5/2	–	–	–	–	14/6	43%
Split Mountain	–	–	–	–	4/4	NA	3/1	4/4	5/5	16/14	88%
Total	0/0	–	5/0	4/4	9/6	–	3/1	4/4	5/5	30/20	66%
Percent Success	–	–	0%	100%	78%	–	33%	100%	100%	66%	–
Sites Activated	1	–	1	1	2	0	1	1	1	8	–

*Four young placed, then removed due to great horned owls

NA=Not activated due to Mormon Cricket spraying.

the cliff top and tape recordings of peregrine vocalizations were played. However, prior to his release, a wild adult tiercel was observed copulating with the female. Because a wild pair was present, the release was discontinued. In 1982, the falcon was absent and only a single tiercel occupied HS. The Peregrine Fund transported two conditioned adult falcons and one adult tiercel and prepared to release one of them. The females were tethered at the cliff edge and tape recordings of courting female vocalizations were played. On the second day, an unidentified peregrine flew in and landed on the cliff, then flew off. On the third day, an immature tiercel flew past the tethered falcons but showed no further interest. Because of his immature status, pairing was highly unlikely and the experiment was terminated. Ultimately, The Peregrine Fund decided to end the project because of the difficulties of training and maintaining captive falcons in a condition adequate for their survival in the wild, as well as the apparent impossibility of ensuring that specific release sites were occupied early in the breeding season by only single, adult peregrines.

2.4 Productivity monitoring

Occupied territories were monitored periodically throughout the reproductive period. Visits were made to confirm presence of courting adults, onset of egg-laying, incubation, hatch of young, and number of young fledged. At the more accessible sites, observers were often able to count the young on the ledge immediately prior to and after fledging. On other occasions, a minimum number fledged was confirmed by counting young on the wing in the vicinity.

Productivity is defined as the number of fledged-age young produced at occupied sites with known outcomes, whether or not the territorial birds bred. Productivity was nonexistent from 1972 through 1976, and strongly influenced by fostering efforts over the next 11 years (1978–1988; Figure 2-10). The number of young fledged annually in Dinosaur NM from 1972 through 2004 is shown in Figure 2-11.

During the first 15 years of the program (1972–1986), production from all pairs in Dinosaur NM was limited to nesting activities at SB, HS, and GO. During that period, 22 breeding attempts produced 46 young (2.09 young per attempt). However, 14 of the breeding attempts were fostered and fledged 35 young (2.69 young per attempt), which masked the probable wild production. Based on average wild productivity of 0.94

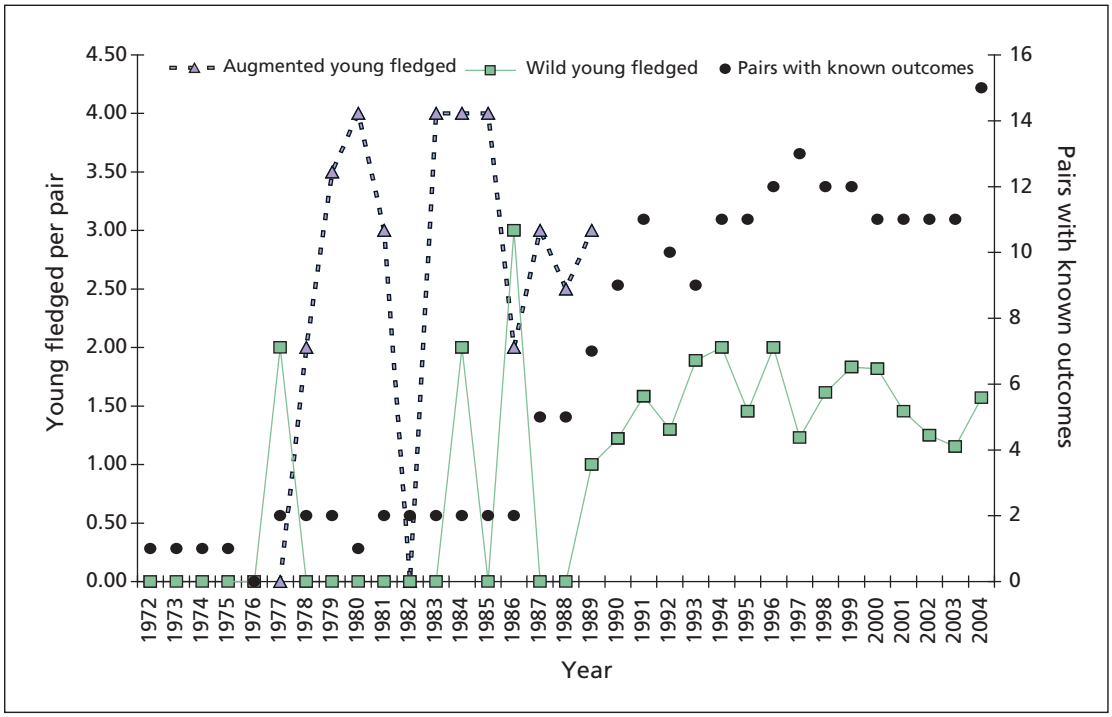


Figure 2-10. Productivity (the number of fledged-age young produced at occupied sites with known outcomes) of peregrines in Dinosaur National Monument, 1972–2004.

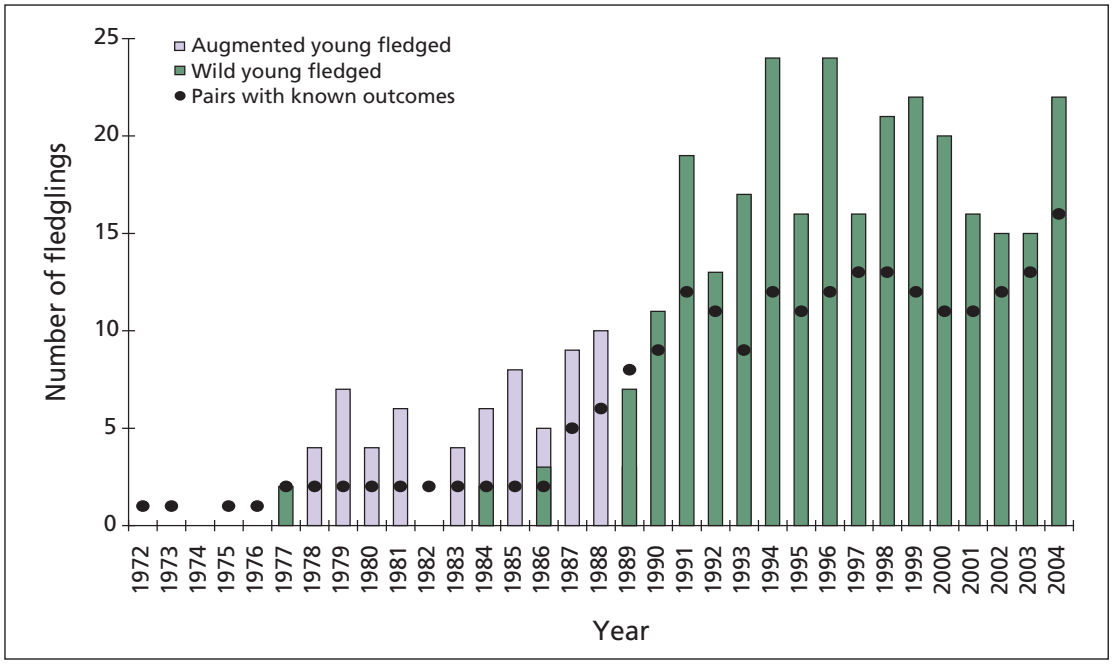


Figure 2-11. Young fledged annually by known outcome pairs of peregrines in Dinosaur National Monument, 1972–2004. Includes wild-produced young and fostered young.

young per occupied site (n=69) experienced elsewhere statewide during the same period (Craig and Enderson 2004), the wild production in Dinosaur NM probably would have mirrored the statewide average. These values are substantially below the critical productivity of 1.22 calculated by Craig, White, and Enderson (2004) as necessary to sustain the population. Only seven young were produced by unmanipulated pairs in nine nesting attempts, so up to 12 more wild young might have been produced if the 14 foster attempts had not occurred.

The number of young produced annually increased as more breeding pairs were established in later years (Figure 2-11). The decline in young fledged from 2001 through 2003 may be partially explained by the vacancy of 3–4 sites annually during those three years. However, productivity (young per occupied site) was also depressed by the failure of 25% (8 of 32) of breeding attempts.

Nine pairs occupied Dinosaur NM by 1990 (see Table 2-1), when fostering efforts were suspended because statewide population goals had been achieved and recovery seemed likely. From 1990 through 2004, 169 breeding attempts produced 271 fledglings, for a productivity of 1.60 young per occupied site. This was almost identical to the statewide productivity of 1.65, as 925 breeding attempts produced 1,529 young (Craig and Enderson 2004). These values are comfortably above the critical productivity of 1.22 calculated by Craig and others (2004) as necessary to sustain the population.

A pattern of fluctuating productivity on alternate years emerged in 1990 and continued through 1998 (see Figure 2-10). A similar statewide annual fluctuation was also apparent for the period from 1994 through 2001 (Figure 2-12). The peaks and valleys evident in Figures 2-10 and 2-12 correspond from 1994 through 1998, although they began earlier in Dinosaur NM and diminished within the monument after 1998. Craig and Enderson (2004) did not speculate on the possible cause for the fluctuation. Similar future patterns will be difficult to detect without consistent annual monitoring.

2.5 Eggshell and pesticide monitoring

One of the stated goals of the Rocky Mountain/Southwest Peregrine Falcon Recovery Plan (Craig 1984) was to reduce shell thinning to 10% or less below pre-decline levels. Monitoring of pesticides and pesticide effects took three forms during the recovery program. One was monitoring of eggshell thickness; another was monitoring of pesticide levels in prey species. Third, whole infertile and dead eggs obtained through manipulation and fostering efforts in peregrine-falcon

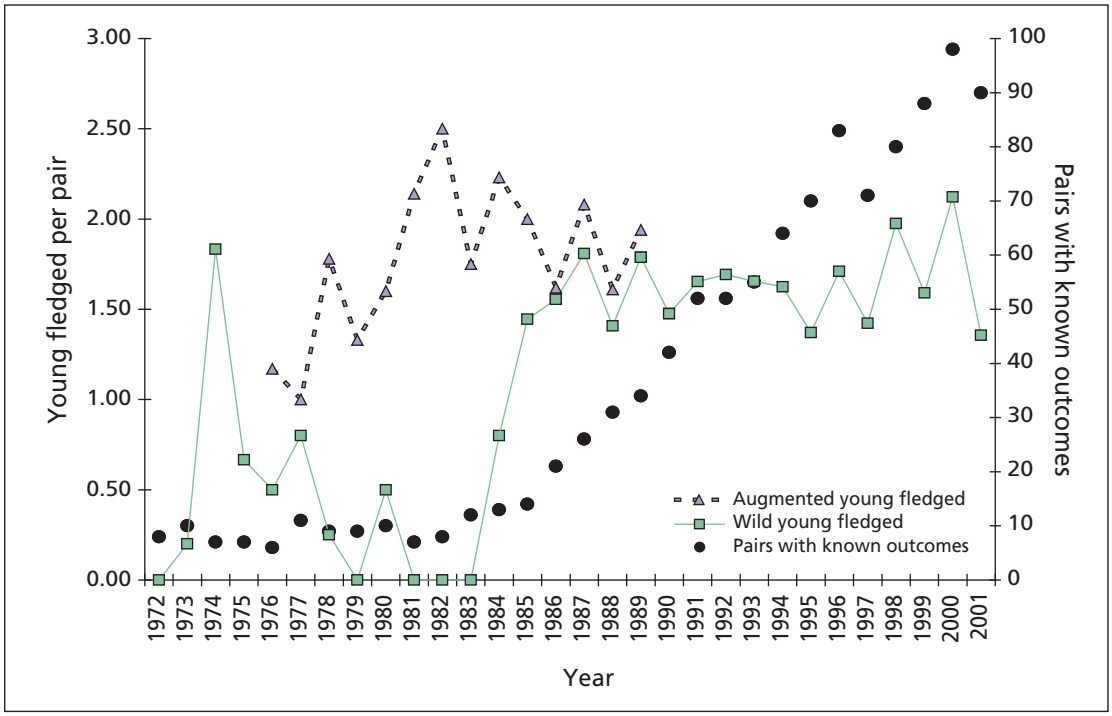


Figure 2-12. Annual productivity of peregrines in Colorado, 1972–2001 (from Craig and Enderson 2004).

eyries in Dinosaur NM provided samples for pesticide analysis to assist in monitoring progress toward the recovery goal.

2.5.1 Eggshell thicknesses

2.5.1.1 Whole shells

Shell thickness was measured optically using a microscope stage micrometer, as described in Craig and Enderson (2004) (see Appendix 3). For comparative purposes, eggshell thickness of 0.359 mm is considered normal for pre-DDT-era peregrine eggs from the Rocky Mountain region. This is based on Anderson and Hickey's (1972) measurements of egg collections obtained prior to widespread application of DDT. The same thickness value of 0.359 mm was established as a benchmark by the Rocky Mountain/Southwest Peregrine Falcon Recovery Team (Craig 1984).

Eggs from Dinosaur NM contributed substantially to the statewide sample of eggs that were measured for shell thickness. From 1977 through 1990, eighty-nine first-clutch eggs were obtained from the Dinosaur NM peregrines (Table 2-5). The resulting eggshells provided insight into thickness changes at four sites (SB, HS, GO, and XM) over a 14-year span.

The shell thicknesses of first-clutch whole eggs (Figure 2-13) followed a trend similar to the statewide population (Figure 2-14), although the correlation was not as strong. Statewide, shell thicknesses improved on average from -17% thin to -4% thin by 1998. Dinosaur NM eggs improved from -16% thin to -8% thin by 1990. Although thinner eggs were encountered more often in early years, it is surprising that the thinnest egg (-25%, 0.269 mm) encountered in Dinosaur NM was collected at GO in 1989. Only three other eggs collected in Colorado were thinner. Although eggshell thicknesses gradually increased over the period 1977–1990, variability was great in later years. The same year the thinnest egg was encountered at GO, the thickest (0.381 mm) was also collected at SB. This represents a thickness range of -25% to +6%.

Large samples of whole eggshells obtained from SB (Figure 2-15) and HS (Figure 2-16) provide trends of thickness changes at individual sites. Both sites exhibited thickness improvement over a 14-year span. Thicknesses tended to be less variable within clutches than among clutches. However, the greatest within-clutch variability occurred at HS in 1983. The clutch of four eggs averaged -5.4% thin (0.339 mm), but ranged from -16.7% thin (0.299 mm) to 5.4% (0.382 mm) thicker than pre-DDT-era eggs. As with the

Table 2-5. Eggs obtained through recycling and fostering efforts, 1977–1990.

Site	Number of eggs in first clutch, second clutch														
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Eggs
GO	–	–	–	–	–	–	–	–	3	–	3	4,3	4,1*	–	14,4
HS	–	3	3,3	–	4	–	4	3	4	4	4	2	–	2,2*	33,5
SB	3	4	3	4	4	4	–	–	–	–	4	3,3	4,3	3,3*	36,9
XM	–	–	–	–	–	–	–	–	–	–	–	4,2*	–	2*	6,2
Total	–	–	–	–	–	–	–	–	–	–	–	–	–	–	89,30

*Site was not revisited after re-nest. Number of eggs is estimated from the number of chicks seen.

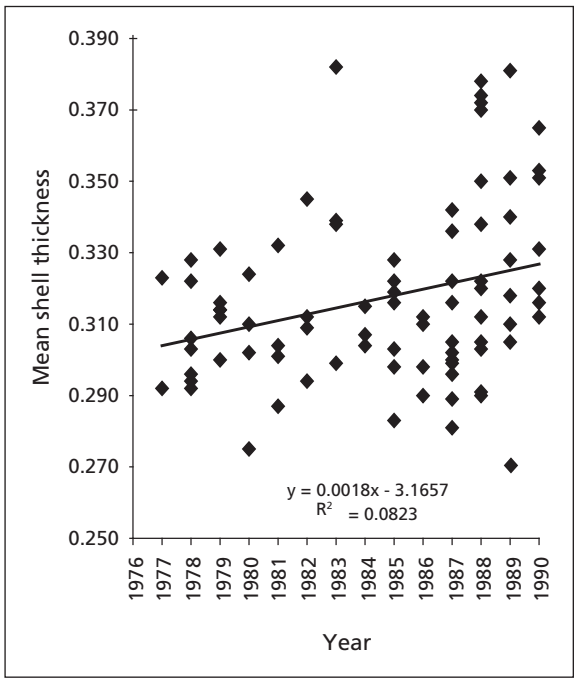


Figure 2-13. Thickness of first-clutch whole eggs collected in Dinosaur National Monument, 1976–1990 (n=80).

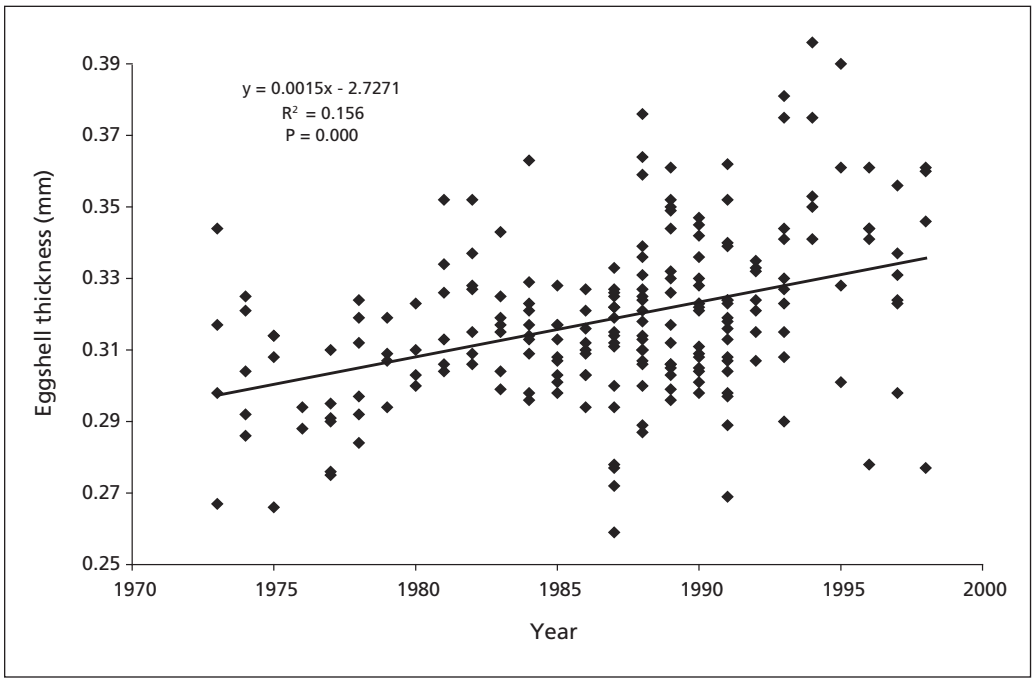


Figure 2-14. Thickness of first-clutch whole eggs collected statewide, 1970–2000 (n=374) (from Craig and Enderson 2004).

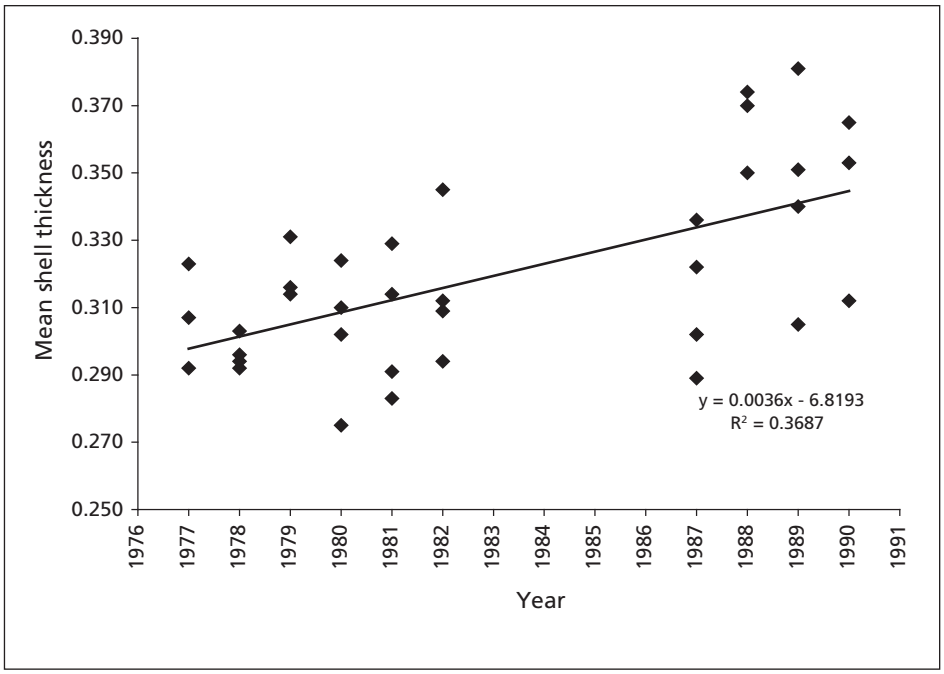


Figure 2-15. Thickness measurements of first-clutch eggs removed from SB, 1977–1990 (n=36).

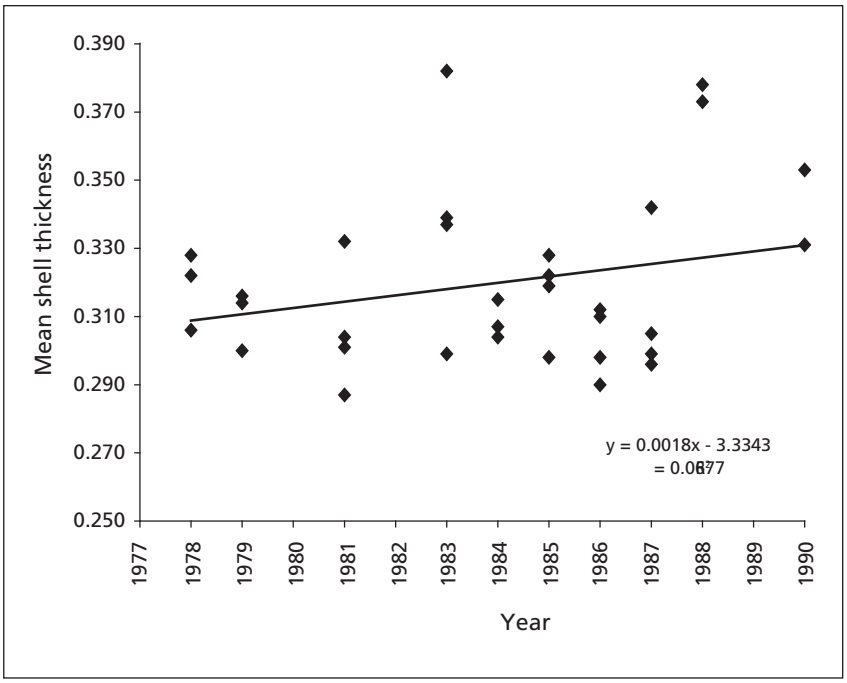


Figure 2-16. Thickness measurements of first-clutch eggs removed from HS, 1978–1990 (n=33).

statewide experience, it is clear that individual shell thicknesses are usually variable within and among clutches and perhaps, to a lesser degree, between clutches from the same site in different years (Craig and Enderson 2004). At best, only general trends will emerge and then only if a sufficient sample of eggshells is obtained.

2.5.1.2 Shell fragments

Eggshell fragments were not encountered at Dinosaur NM. All laying pairs were kept under surveillance and the eggs were removed within 10 days of laying. Hence, there was little time for thin eggs to break under incubating falcons. Craig and Enderson (2004) examined the value of measuring random fragments. Because thickness varies from the waist of the eggs to the poles, they concluded that too much variability was introduced to reflect whole egg measurements taken at the waist of the eggs. If eggshells are collected in the future, measurements should be taken from whole eggs.

2.5.2 Pesticides

2.5.2.1 DDE in eggs

Whole, nonviable eggs were occasionally encountered in the course of recycling and augmentation efforts in Dinosaur NM from 1977 through 1990. Among the 80 eggs collected, 17 were either infertile or did not develop under artificial incubation and were retained for chemical analysis. We recognize that analyzing nonviable eggs may have skewed the results, but wild eggs were too critical to the recovery effort to sacrifice. Laboratory methods are presented in Appendix 3. Residues of nine different pesticides from eggs of 13 clutches are presented in Table 2-6. Because all eggs within a single clutch usually do not

Table 2-6. Levels of pesticide residue and other compounds found in peregrine falcon eggs at Dinosaur National Monument, 1977–1990.

			ppm (wet weight)								
Year	Sample*	Thickness (mm)	DDE (log)	DDT	Dieldrin	PCBs	HCB	βBHC	Oxy-chloride	Heptachlor epoxide	Mirex
1977	SB1,3	0.292	9.60 (0.98)	N.D.	N.D.	0.60	0.16	N.R.	N.R.	N.R.	N.R.
1979	HS1,2	0.303	32.00 (1.51)	2.00	0.12	2.00	N.R.	0.18	0.15	0.36	0.18
1979	HS1,3	0.303	32.00 (1.51)	2.00	0.13	2.20	N.R.	0.18	0.17	0.40	0.18
1980	SB1,3	0.275	13.00 (1.11)	0.28	0.17	2.00	N.R.	N.R.	0.15	1.13	N.R.
1981	SB1,1	0.309	20.40 (1.31)	0.17	N.D.	1.20	N.R.	N.R.	0.20	2.60	N.R.
1981	SB1,2	0.282	17.80 (1.25)	0.26	N.D.	1.20	N.R.	N.R.	0.18	2.40	N.R.
1981	SB1,3	0.289	17.20 (1.24)	0.21	N.D.	0.80	N.R.	N.R.	0.16	2.20	N.R.
1982	SB1,2	0.332	32.00 (1.50)	0.14	0.23	1.10	N.R.	N.R.	0.23	1.40	N.R.
1983	HS1,3	0.338	19.20 (1.28)	0.36	0.11	0.95	N.R.	N.R.	0.09	0.32	N.R.
1984	HS1,1	0.315	24.30 (1.39)	0.93	0.14	0.86	N.R.	N.R.	0.10	0.31	N.D.
1985	HS1,4	0.319	12.60 (1.10)	12.60	N.D.	0.63	N.R.	N.R.	0.08	0.21	N.D.
1986	HS	0.289	10.70 (1.03)	0.52	N.D.	0.89	21.00	N.R.	N.R.	N.R.	21.43
1987	HS	0.299	13.60 (1.13)	0.31	N.D.	0.47	8.93	N.R.	N.R.	N.R.	7.17
1987	GO	0.281	9.70 (0.97)	0.82	3.00	1.72	247.50	N.R.	N.R.	N.R.	30.00
1988	GO	0.338	7.50 (0.87)	0.01	1.71	0.94	7.60	N.R.	N.R.	N.R.	22.17
1990	XM1,1	0.318	2.37 (0.37)	N.D.	N.D.	2.45	N.D.	N.D.	0.04	0.05	N.D.
1990	XM1,2	0.316	4.70 (0.67)	N.D.	0.12	7.50	0.04	N.D.	0.09	0.19	0.02

*Notation in this column indicates the sample site, clutch number, and egg number. For example, SB1,3 would represent the SB site, first clutch, third egg.

DDE: Dichlorodiphenyldichloroethylene (organochlorine pesticide); DDT: Dichlorodiphenyltrichloroethane (organochlorine pesticide); Dieldrin:organochlorine pesticide; HCB: hexachlorobenzene; Heptachlor epoxide: Compound created when the organochlorine pesticide, heptachlor, is released to the environment and mixes with oxygen; Mirex: organochlorine pesticide; Oxychloride: a compound having oxygen and chlorine atoms bonded to another element; PCBs: polychloride biphenyls; βBHC: benzene hexachloride, a chlorinated pesticide

vary by more than a few parts per million (Enderson et al. 1988), multiple egg clutches (HS79, SB81, and XM90) were averaged to obtain single values for comparison with single eggs from other clutches.

Although low levels of DDE may cause shell thinning, it is generally accepted that egg breakage is likely when DDE exceeds about 20 ppm (wet weight) in egg contents (Fyfe et al. 1988). Eight of 10 eggs collected from 1977 through 1984 were near 20 ppm. Only one of the 10 was below 10 ppm (Table 2-7). Three of the seven eggs collected from 1985 through 1990 were slightly over 10 ppm. The other four were less than 10 ppm.

DDE residues of eggs collected from 1977 through 1990 were converted to log values and are presented in Figure 2-17. From the limited sample, it is apparent that DDE contamination has declined (R^2=0.5034, P <0.001) in peregrines inhabiting Dinosaur NM. This trend is similar, but less pronounced in the larger (n=82) statewide sample collected during the same period (Figure 2-18).

2.5.2.2 DDE and shell thickness

Enderson and others (1988) postulated that DDE residues in eggs reflect the laying falcon's overall body burden of the chemical, while eggshell thickness is more variable and related to the prey items eaten by the falcon during each individual two-day laying event. Some prey species carry little DDE. Others carry heavy loads (see Section 2.5.3). White-throated swifts (*Aeronautes saxitalis*) and other insectivores had substantially higher loading of DDE than did mourning doves (*Zenaida macroura*) and other granivores (DeWeese et al. 1986). If the falcon feeds on contaminated prey, such as white-throated swifts or killdeer (*Charadrius vociferus*), then she is exposed to higher loads and the forming egg may have a thinner shell.

Eggshell thickness of Dinosaur NM eggs did not correlate with DDE in the contents of individual eggs (Figure 2-19), probably because the small sample (n=17) was not sufficient for trends to emerge. The larger statewide sample (n=80) did exhibit a correlation (R^2=0.0454, P<0.001) between DDE residues and eggshell thinning (Figure 2-20).

Although the data are not clear, the most important prey of Dinosaur NM peregrines—swifts—are likely exposed to DDT on their winter ranges and utilized by some peregrines in both the summer and winter. Because it is fat-soluble, DDE is accumulated in the falcon's body over her lifespan, although the body burden should decrease incrementally when some DDE is mobilized and excreted whenever fat is used, such as in egg formation. Therefore, DDE levels and related eggshell thinning should increase as contaminated prey is consumed and decline with abatement of pesticide application. It appears that falcons on some Dinosaur NM territories may have an effective breeding life of 10 years or more. Identifiable individual falcons were on territories for eight, nine, and 11 years.

Elsewhere in Colorado, one female lived 14 years (Craig and Enderson 2004). If the environment has progressively less DDT, then one should not be surprised to see a decline in shell thinning over the breeding life of an individual falcon. Further, if the environment does have progressively less DDT, new falcons coming of breeding age would likely have a smaller DDE load than their predecessors. Perhaps this provides some explanation, either with a long-lived falcon or a succession of falcons, of the slight increase in shell thickness evident in SB and HS clutches from 1977 through 1990 (see Figures 2-15 and 2-16).

2.5.2.3 Other residues

DDE was of primary concern because it causes shell thinning. However, other deleterious compounds (Dieldrin, Mirex, and PCBs) were also detected in some of the assays of egg contents. Table 2-6 lists other chemicals that were encountered. Although concentrations were not sufficient to be of immediate concern, they have been provided for future reference.

2.5.3 Pesticide loading in prey species

In 1978, 1979, and 1981, potential prey species utilized by peregrine falcons were collected in Dinosaur NM and elsewhere in the western United States to determine levels of pesticide loading. Under appropriate federal permits, 8–10 specimens of several species

Table 2-7. Prey captured by peregrines at nest sites in Dinosaur National Monument, recovered (R) as prey remains in eyries (n=63) or observed (O) captured (n=23).

		AH		CE		GO		HA		HS		OP		PC		RP		SB		TG		XM		
Common name	**Scientific name**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**R**	**O**	**Total**
White-throated swift	*Aeronautes saxitalis*	–	1	–	1	1	–	–	–	6	1	2	–	–	–	–	–	4	–	–	–	–	–	16
Mourning dove	*Zenaida macroura*	–	–	–	–	1	–	1	–	2	1	2	–	–	–	–	–	3	–	–	–	1	–	11
Pinyon jay	*Gymnorhinus cyanocephalus*	–	–	–	–	2	–	–	–	1	1	1	–	–	–	–	–	–	–	–	–	–	–	5
Brewer's blackbird	*Euphagus cyanocephalus*	–	–	–	–	1	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	1	4
Common nighthawk	*Chordeiles minor*	–	–	–	–	–	–	–	–	2	1	–	–	–	–	–	–	1	–	–	–	–	–	4
Violet-green swallow	*Tachycineta thalassina*	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	1	–	–	1	–	–	4
Western meadowlark	*Sturnella neglecta*	–	–	–	–	–	–	–	–	2	1	–	–	–	–	–	–	1	–	–	–	–	–	4
Clark's nutcracker	*Nucifrara columbiana*	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	1	–	–	–	–	–	3
Common flicker	*Colaptes auratus*	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	1	3
American kestrel	*Falco sparverius*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	2
American robin	*Turdus migratorius*	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	2
Common raven	*Corvus corax*	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	2
Mountain bluebird	*Sailia curricoides*	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	2
Red crossbill	*Loxia curvirostra*	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	2
Vireo sp.	*Vireo* sp.	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	2
Belted kingfisher	*Ceryle alcon*	–	–	–	–	–	–	–	–		–	1	–	–	–	–	–	–	–	–	–	–	–	1
Brown-headed cowbird	*Moluthrus ater*	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Canyon wren	*Catherpes mexicanus*	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Chipping sparrow	*Spizella passerine*	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
European starling	*Sturnus vulgaris*	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
Killdeer	*Charadrius vociferus*	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Loggerhead shrike	*Lanius ludovicianus*	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Rose-breasted grosbeak	*Pheuciticus ludovicianus*	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Say's phoebe	*Sayornis saya*	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Unidentified blackbird	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	2
Unidentified jay	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Chipmunk	*Tamias* sp.	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Unidentified bat	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–		–	–	–	–	–	1
Unidentified small mammal	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Mormon cricket	*Anabrus simplex*	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	2
Total	–	0	1	0	1	8	1	1	1	24	10	12	0	0	2	0	1	15	2	0	1	1	2	83

Figure 2-17. DDE residue in contents of eggs collected in Dinosaur National Monument, 1976–1990 (n=13).

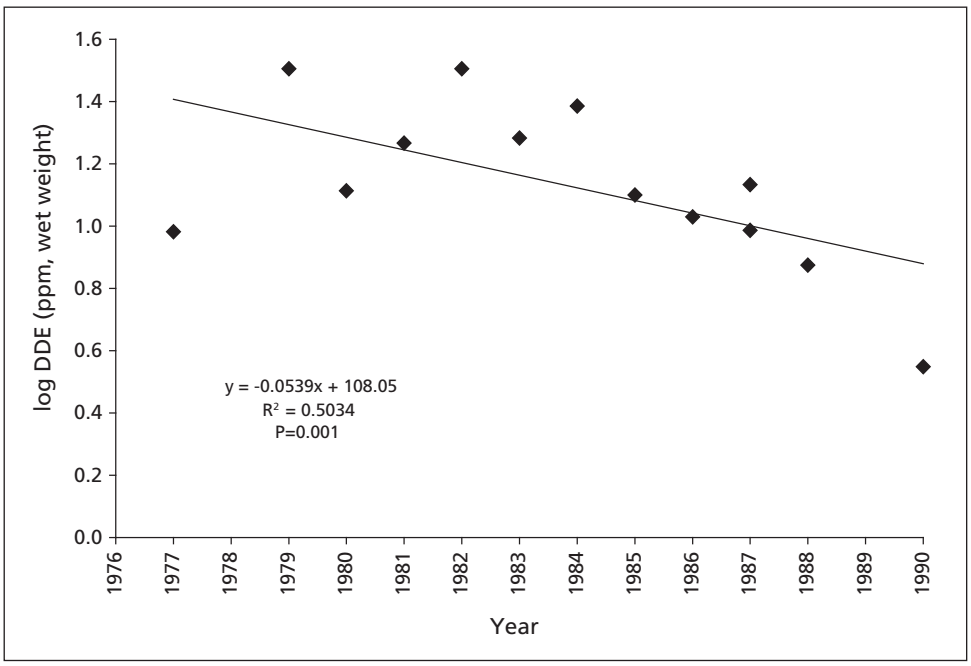
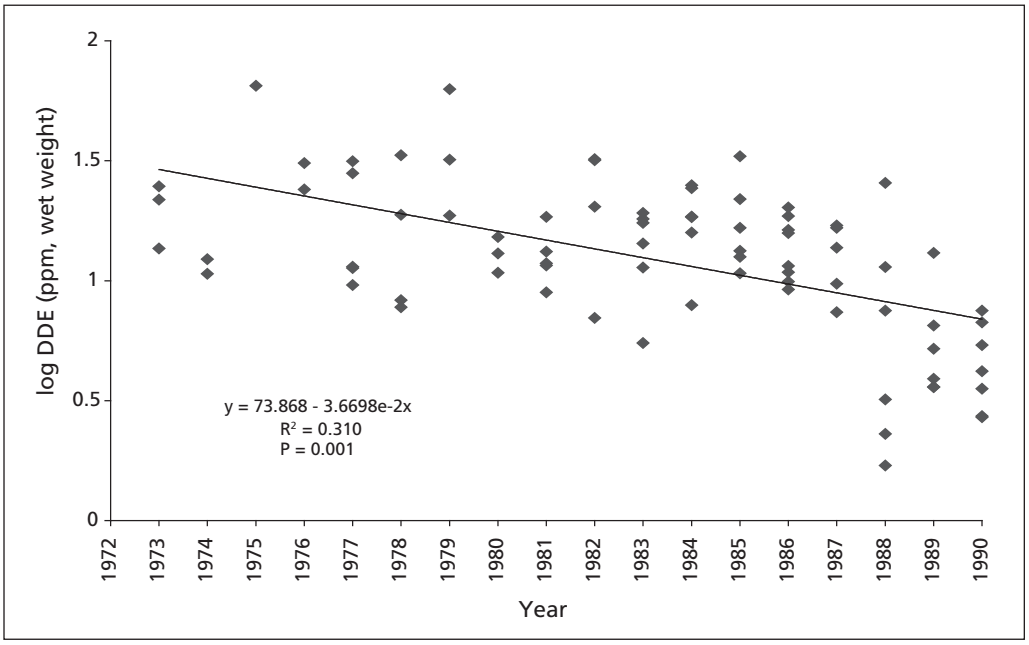


Figure 2-18. DDE residue in contents of eggs collected statewide, 1972–1990 (n=82) (from Craig and Enderson 2004).



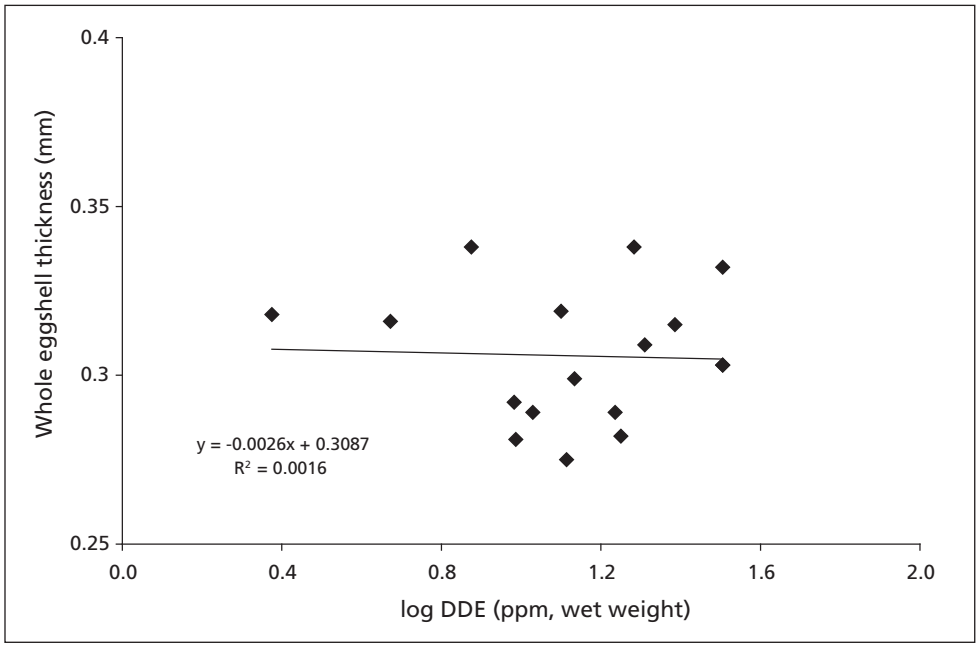


Figure 2-19. Eggshell thickness compared to DDE in contents of whole eggs from Dinosaur National Monument (n=17).

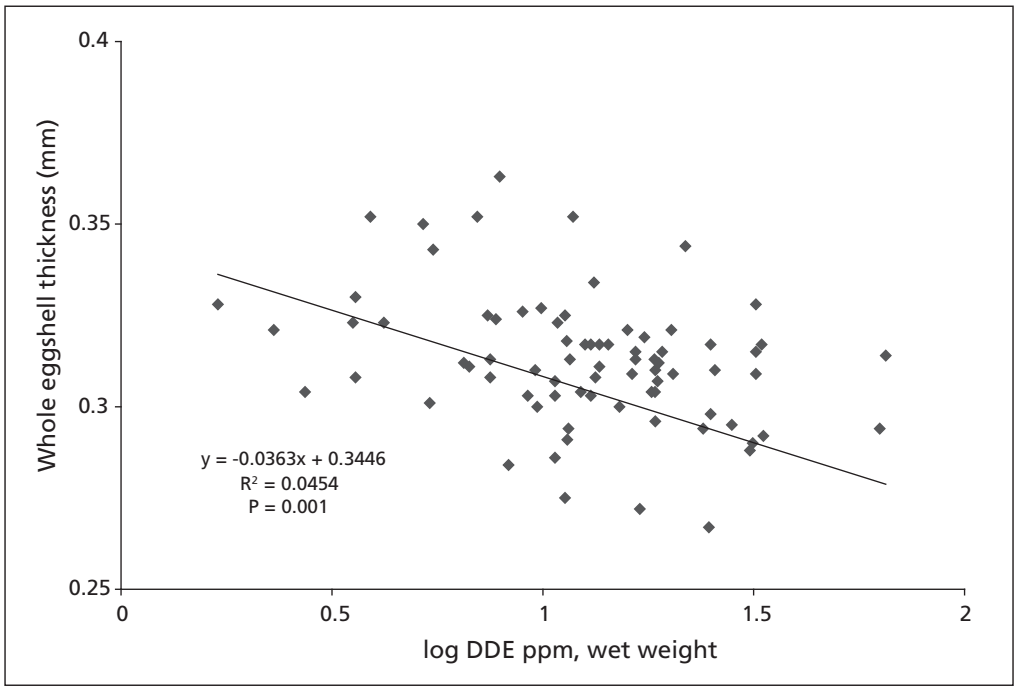


Figure 2-20. Eggshell thickness compared to DDE in contents of eggs collected statewide (n=80) (from Craig and Enderson 2004).

were collected with shotguns near peregrine nests between May and June in each year. Specimens were frozen within eight hours and submitted to the Patuxent Wildlife Research Center for analysis. Samples were prepared and analyzed following protocols established by the Patuxent Wildlife Research Center. Collections were made outside the monument but within the hunting range of the two known peregrine eyries.

Species collected in 1978 included killdeer, white-throated swifts, violet-green swallows (*Tachycineta thalassina*), cliff swallows (*Petrochelidon pyrrhonota*), mountain bluebirds (*Sailia curricoides*), American robins (*Turdus migratorius*), mourning doves, western meadowlarks (*Sturnella neglecta*), Brewer's blackbirds (*Euphagus cyanocephalus*), red-winged blackbirds (*Agelaius phoeniceus*), flickers (*Colaptes auratus*), black-billed magpies (*Pica hudsonia*), and western kingbirds (*Tyrannus verticalis*). Sampling in 1979 and 1981 focused mostly on swifts and swallows. Samples from Dinosaur NM were aggregated with specimens collected at 35 other locations in eight western states (CO, ID, MT, NM, OR, SD, UT and WY) and provide a regional perspective of potential organochlorine residues in peregrine prey (DeWeese et al. 1986).

DeWeese and others (1986) found DDE in virtually all of the collected specimens. Those with the highest loadings were migratory insectivores (e.g., white-throated swifts, violet-green swallows) and shorebirds (e.g., killdeer). Levels in migratory species were about 13 times higher than those in non-migratory species. The pooled samples showed the following average level of DDE in parts per million (ppm) wet weight: killdeer, 11.43 ppm; violet-green swallow, 3.87 ppm; cliff swallow, 3.18 ppm; Brewer's blackbird, 2.63 ppm; and white-throated swift, 1.88 ppm. On the other end of the spectrum were robins (0.67 ppm), flickers (0.07), and mourning doves (0.05 ppm). DeWeese and others (1986) noted that 3 ppm of DDE in prey species was considered sufficient to inhibit normal reproduction in certain avian predators.

Samples collected in Dinosaur NM in 1978 were independent of the regional collections coordinated by Deweese and others (1986) in 1979–1980 and provide additional insight into local contamination in Dinosaur NM. Residue levels in Dinosaur NM were similar to those of most other species throughout the region in 1978. However, DDE levels were three times higher in killdeer (31.7 ppm) and Brewer's blackbirds (6.0 ppm). Residues in violet-green swallows averaged 5.9 ppm. Tree swallows, which were not sampled elsewhere, experienced body burdens of 32.8 ppm. Lincer (1975) reported that dietary DDE of 3 ppm, 6 ppm, and 10 ppm caused an average eggshell thinning of 14.0%, 17.4% and 21.7%, respectively, in captive kestrels (*Falco sparverius*). Any peregrine prey with DDE loading in the 5–6 ppm range would therefore be of concern. The results of this sampling, which has not been repeated in recent years, is that there were sufficiently high DDE loadings in prey species commonly utilized by peregrines to continue to cause eggshell thinning even 6–8 years after use of DDT was restricted in the United States.

2.5.4 Prognosis

There is a clear and direct effect of DDE on peregrine falcons (Peakall and Kiff 1988). Although the relationship was less clear in Dinosaur NM alone (see Figure 2-19), there was a significant correlation between eggshell thickness and DDE in egg contents throughout Colorado (see Figure 2-20).

Use of DDT in the United States was restricted in 1972 because of the apparent effects on several species, most notably the bald eagle (*Haliaeetus leucocephalus*). Thus, over time, the amount of DDT in the environment—with simple reasoning—should be expected to decline. That appears to be evident both statewide and in Dinosaur NM, based on DDE residues in egg contents (see Figures 2-17 and 2-18).

Why, then, haven't eggshell thicknesses returned to pre-DDT levels, and why such variation within clutches? A couple factors may contribute to the situation. First, while the use of DDT was restricted in the United States, it still was and is used extensively in Central America. Migratory prey species—especially insectivores, such as white-throat-

ed swifts and violet green swallows—can accumulate DDE while on their winter ranges. Peregrines can still accumulate DDE when they feed on these species, both on summer and winter ranges.

A second factor is other pesticides. When chemical companies register a pesticide with the U.S. Environmental Protection Agency (EPA), they only register the identified active ingredient; the remainder of the formulation is considered "impurities." Shortly after DDT was restricted in the United States, a whole new family of pesticides—called dicofols—was registered with EPA. One of the more common trade names within this family is Kelthane. Many of this family of dicofols initially had lots of impurities—up to 40% or more by weight. DDT was the main impurity. Current federal law requires that DDT content be reduced to less than 1% in Kelthane. In short, DDT is still being applied under different labels—and demand may increase as public health is threatened by new insect-borne diseases.

2.6 Natural history studies

2.6.1 Prey

Peregrines feed almost exclusively on other birds. Prey encountered at Dinosaur NM eyrie sites are summarized in Table 2-7. The majority of records (63) were obtained in the course of visits to nest ledges to remove eggs and return captive hatched young. Other prey records (23) were reported by observers at eyrie sites. The majority (71%) of prey items on record were encountered at three sites that were manipulated (SB, HS, and GO) and hence received more observation time than other sites. White-throated swifts accounted for 19% of the prey, followed by mourning doves (13%). Swifts (17% of all remains of individuals) and doves (13%) were also ranked highest in prey taken statewide (n=865) (Craig and Enderson 2004).Observers recorded 23 prey items captured near or brought to the nest cliff. Although numerous prey transfers were witnessed, items frequently could only be identified as "small dark birds" because of the distance and brevity of observations. Larger species with unique feather patterns were more likely to be recorded. Two common raven (*Corvus corax*) kills were documented: a fledgling peregrine was feeding on the wing of a raven at PC and a mature male at HS was video-recorded bringing in a whole raven. Remains of two fledged American kestrels were encountered under a favorite plucking perch at SB. Peregrine were twice seen feeding on mallard (*Anas platyrynchus*) kills, one within four miles of CE and again a similar distance from RP.

On two occasions, incubating or brooding falcons ate Mormon crickets when they came within reach. Cricket bands were not hampered by escarpments, negotiated vertical walls, and occasionally crossed nest ledges. The falcon at RP ate a single cricket (but did not seem to relish it), while the incubating falcon at GO repeatedly consumed crickets from a passing band as they came within reach.

2.6.2 Breeding chronology

Because late snow and mud in March often hampered access within the monument, early arrivals of peregrines to territories were not documented. However, pairs were already on territory, some with eggs, in early April. Although onset of egg-laying was infrequently observed (except in the early years of intensive monitoring at one or two eyries), initiation of egg-laying could be obtained by back-dating. Back-dating was applied when eggs were candled (i.e., held in front of a beam of light so the stage of embryo development can be determined; the term has probably carried over from the time when a candle served as the source of light) and aged as they were brought into The Peregrine Fund's incubation facilities (n=24 clutches) and when eyasses were observed in the eyrie. For the latter, an eyass's size and feather development was compared to a photographic guide to estimate age within several days (Moritsch 1983). Initiation of egg-laying or fledge was then calculated, assuming the following parameters:

- The interval from laying of the first egg to clutch completion was seven days, assuming a clutch of 3–4 eggs that are laid every other day.

- Initiation of incubation occurs upon clutch completion.
- Eggs generally hatch 33 days after initiation of incubation.
- Males fledge at 40 days and females fledge at 42 days.

Initiation dates of 138 first clutches are displayed in Figure 2-21. The median date for the monument was April 22, compared to the statewide median of April 14 (Craig and Enderson 2004). A weeklong delay might be expected, given the more northern latitude of the monument's nest sites. The earliest eggs were laid on March 28 (AH, in 2000). The next-earliest eggs were laid on March 30 (HS, in 2004), April 1 (AH, in 1999), April 3 (HS, in 2003), and April 4 (HS, in 1998). Although AH and HS exhibited earliest egg-laying, the majority of clutches at AH (8 of 14) and HS (14 of 21) were initiated after April 20. Clutches initiated late in the season may have been re-nesting attempts. If a clutch of eggs is lost early in incubation, re-nesting will often occur about 14 days after failure. Eggs laid after May 1 were the result of re-nests in 26 cases (4%) statewide. Second clutches at SB occurred on May 10, 1999, and May 6, 2004. However, seven additional clutches laid after May 1 were believed to be first efforts. Because eggs generally hatch after 33 days of incubation and fledging occurs at about 42 days, similar date curves were generated for hatch and fledge (Figure 2-22).

The latest birds were observed on territory was October 3, 2003, when Steve Petersburg saw the falcon and one young on the wing at the HS eyrie. Petersburg also observed birds in late September at the GL eyrie. Usually, most nesting territories were vacant in mid- to late August.

2.6.3 Movements

Low band-recovery rates for raptors are typical. Unless large numbers of falcons are banded, movement information will be sparse. Although 938 falcons were marked statewide over a 30-year period in Colorado, only 53 recoveries (5.6%) were reported (Craig and Enderson 2004). In the course of the Dinosaur NM investigation, anodized markers and USFWS bands were placed on 125 eyasses (72 fostered, 30 hacked, and 23 wild-produced). Recoveries were reported for only three nestlings (2.4%) banded in Dinosaur NM. A fourth encounter was an adult falcon, marked elsewhere, that nested at HS.

2.6.3.1 Migration

A fostered tiercel, banded as an eyass at SB in 1980, was hand-caught, then released on the Panama coast at Chilibre, on November 3 of that same year. This was the longest move-

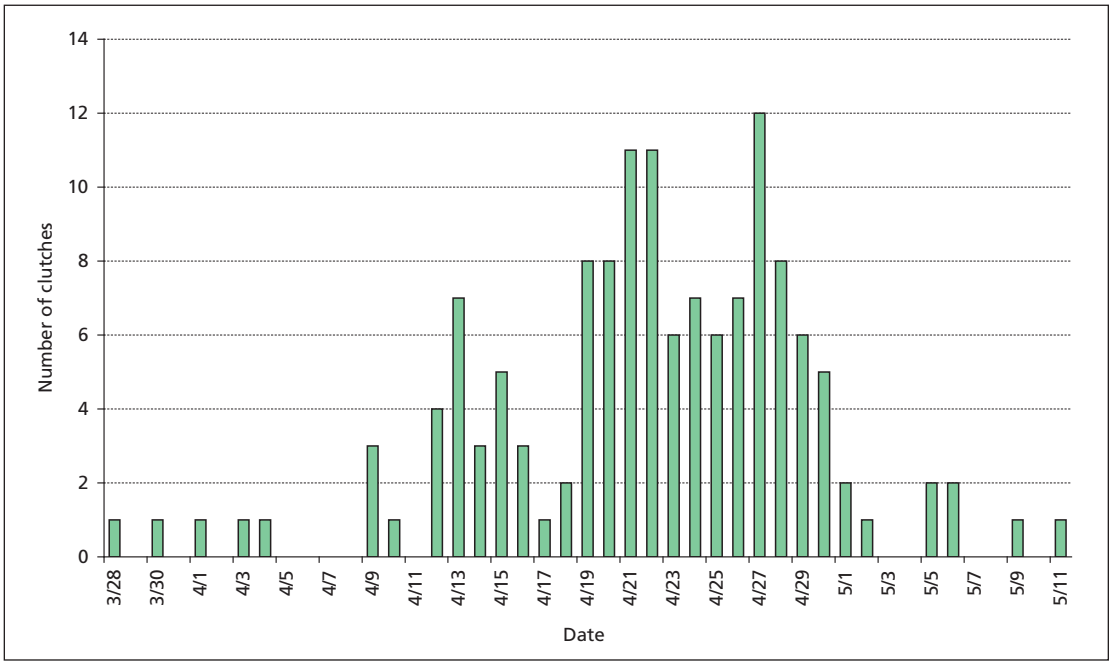


Figure 2-21. Initiation dates of first clutches for Dinosaur National Monument peregrines, 1982–2004 (n=138).

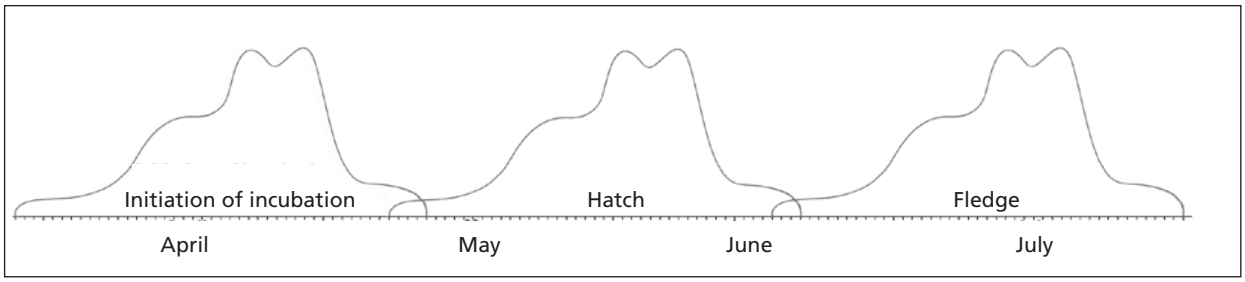


Figure 2-22. Breeding sequence of Dinosaur National Monument peregrines.

ment of first-year Colorado peregrines documented by Craig and Enderson (2004). The falcon may have continued farther south, given the encounter date. The prognosis for this bird was not good, however, because it was sufficiently debilitated to be caught by hand.

2.6.3.2 Wintering

The desiccated carcass of a wild-produced female, banded at OP in 1993, was found on an island in Lake Guerrero, Guerrero Province, Mexico, in February 1995. The lake hosts large numbers of shorebirds and waterfowl and is hunted by sportsmen from abroad.

2.6.3.3 Breeding

An adult female that wintered on a water tower near the rail yards in Grand Junction, Colorado, for several years was encountered with a broken wing in late winter 1987. She was rehabilitated and released September 15 of that same year. In spring 1988, this falcon was observed breeding at HS and she returned to rear young at the site again in 1989. In 1990, she was replaced by an unbanded female midway through incubation. This falcon was unusually tolerant of people. She nested high on the cliff and would land within six feet of the climber when the eyrie was visited (Figure 2-23).

A female fostered at HS in 1985 was trapped at her eyrie on Lake Powell 10 years later by Mike Britten as part of a National Park Service telemetry study in 1995. The falcon had established her breeding territory 272 miles from her natal site in Dinosaur NM.

2.6.4 Mortalities

2.6.4.1 Nestlings

Loss of nestlings from broods was encountered on 33 occasions. Ninety-one young were originally present in the broods (2.76 young per brood) and 48 (53%) died prior to or during fledge. In all but six cases, the eyasses simply were not present on subsequent visits and the cause of mortality was not determined. Dead young were encountered on the eyrie ledge in three instances. Two dead nestlings were less than two weeks of age and

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Figure 2-23. Adult female perched at eyrie below climber.

the other was over four weeks old. Because the carcasses were present, death may have been developmental or by starvation rather than predation. No cause could be determined for loss of entire broods on eight occasions, although the disappearance of the adult falcon was suspected in the failure at GO in 2003. Death of the adult falcon to a great horned owl at HS in 1981 might have resulted in failure without human intervention (see Section 2.3.3). Four of the eight lost broods were single eyasses and the loss resulted in site abandonment. Loss of a single eyass from broods with multiple young was probably not noticed by the adults.

Avian predation was observed at three sites. An eyass was apparently dragged off the ledge during the above-mentioned owl attack at HS. It fell to a lower ledge and died the following day. In 1981, a golden eagle attacked a brood of four fledglings at SB as they exercised on the ledge. The eagle dashed a fledgling against a cliff and retrieved it as it fell. Two other young fledged prematurely but were not injured. It is likely that older eyasses are vulnerable to predation, as they are inattentive while exercising and competing for prey. The adults are occupied supplying food to large young and may not be in the vicinity to defend against the attacks. Repeated golden-eagle attacks during the hacking effort at Deerlodge Park also resulted in loss of three of five fledglings in 1984.

Wildland fires occurred during the fledge stage at GL in 2000 and HS in 2002. Two large young were seen on the ledge at GL prior to the fire, but only one fledged. The fire burned to the cliff edge above the eyrie. Despite orders to the contrary, helicopters repeatedly flew past the cliff face and secured water from the river immediately upstream of the site. The prolonged disturbance may have been a factor in the demise of the fledgling. The fire at HS also burned most of the vegetation from the top of the cliff during the fledge stage. Firefighting efforts were planned to avoid disturbance to the eyrie and all fledged without incident.

Accidental deaths also occurred. Observers watched the ill-fated maiden flight of a fledging tiercel at SB in 1990. The fledgling flew about 150 feet from the eyrie and attempted to land on a small protuberance at the same level. The bird eventually lost balance and hung upside down for several minutes before dropping away. The bird regained flight and momentarily soared away from the cliff, then made several attempts to perch on the sheer wall below the eyrie ledge. After the third attempt, about 300 yards upstream from the nest ledge, the peregrine tumbled out of sight, making no effort to fly. Its carcass was later located and retrieved from the talus about three feet from the cliff face. A necropsy revealed a fractured sternum, probably caused by impact with the cliff face.

2.6.4.2 Adults

As of this writing, no band recoveries of adult peregrines had been reported. Remains of an adult male peregrine were found below the nest cliff at SB on July 6, 1998. The cause of death was undetermined. A lone adult was observed on subsequent visits and successfully fledged three young. It is probable that the dead adult was a member of the pair.

3 Future Monitoring

Future survey frequency and sampling effort will depend upon resources, occupancy, and productivity trends within Dinosaur NM and regionally. Unforeseen threats, such as West Nile virus and avian flu, also may require more frequent or detailed monitoring. Sites that experience loss or alteration of nesting or foraging habitat, or human visitation within sensitive areas, should be monitored to assess impacts of habitat alteration or human activities.

3.1 Priority sites

At time of writing, 20 nesting territories had been identified within or immediately adjacent to Dinosaur NM (15 were on record in 2004). Personnel and fiscal restraints necessitate prioritizing the territories to be monitored in the future. Each of the territories on record in 2004 was scored from 1 to 5, in descending value, relative to three factors: remoteness (accessibility to survey teams), ease of observation, and history (years of documented occupancy) (Table 3-1). Sites that consume inordinate travel time received higher scores than sites that could be more easily accessed, thereby permitting multiple visits by observers. Sites receiving lower overall scores were ranked higher in the survey priority.

Higher ranks were awarded to territories with unobscured cliff faces and nest ledges that permitted observers to confirm presence of incubating adults, eggs, and young. Several territories (AH, BJ, HS, OP, SB, and XM) have nest ledges on escarpments that are easily viewed, while other ledges are out of sight. In these cases, "observability" was based upon the majority of known nest ledges within the territory.

Finally, those sites with the longest history of occupancy contribute most to understanding population trends and were assigned higher ranks. Table 3-1 assigns monitoring priorities for each site according to scores accrued in the three categories. The only exception is GO, which was ranked third but assigned first priority. The USFWS designated GO among the sample of Colorado sites to be monitored once every third year from 2001 through 2014 to ensure that the species's population remains secure, as mandated in the Endangered Species Act's post-delisting monitoring protocol (USFWS 2003). Therefore, it is important that GO be monitored in 2006, 2009, 2012, and 2014.

It should be noted that focusing only on the known territories (priority sites) will freeze Dinosaur NM's population information at 2004, when the last site (HA) was reported. Inventories of potential cliffs should also continue in order to document population fluctuation. Those sites most recently occupied are likely to be in more marginal locations and to be abandoned first should the population decline. Three decades of peregrine data provide a unique opportunity to monitor and research a population as it reaches carrying capacity.

Table 3-1. Monitoring priority for Dinosaur National Monument sites.

Site	Accessibility	Ease of observation	History	Total	Rank	Survey priority
GO	3	2	2	7	3	1*
HS	1	1	1	3	1	2
SB	1	3	1	5	2	3
HA	1	1	5	7	4	4
AH	3	3	2	8	5	5
BJ	5	2	2	9	6	6
GL	3	4	2	9	7	7
JH	2	4	3	9	8	8
OP	2	4	3	9	9	9
SC	3	3	4	10	10	10
XM	2	4	3	9	11	11
CW	2	4	5	11	12	12
CE	2	4	5	11	13	13
TG	3	3	5	11	14	14
RP	3	5	4	12	15	15
PC	5	3	4	12	16	16
RB	5	4	5	14	17	17
SM	5	5	5	15	18	18

Factors are scored 1–5, in descending value.

*GO is a mandatory USFWS monitoring site and will receive highest priority at 5-year intervals in 2001, 2006, 2011, and 2016.

3.2 Sampling

Ideally, all known sites and potential cliffs should be surveyed. However, funding does not always support the ideal. Statistically, little can be accomplished with sampling the limited number of sites (n=20) associated with the monument. It is more appropriate to assign the number of sites that a team of competent observers might reasonably visit in a breeding season. Typically, 3–4 visits must be made throughout the breeding season to obtain information on site occupancy and productivity (Craig and Enderson 2004). More time can be devoted to observation if the more accessible and observable sites are visited. Therefore, a team should be able to monitor 8–10 territories by following the order of priority established in Table 3-1.

3.3 Survey frequency

Ideally, a representative sample of peregrine nest sites should be monitored annually on a statewide basis (Craig and Enderson 2004) and the top seven priority sites in Dinosaur NM (GO, HS, SB, HA, AH, BJ, and GL; see Table 3-1) should be included as an important subset of that work. However, if the frequency of statewide monitoring is reduced, then Dinosaur NM may scale back efforts to meet the monument's needs as prescribed in the Northern Colorado Plateau Network's monitoring protocol (Daw et al. 2006). In addition, one site (GO) was designated to be visited every three years by the U.S. Fish and Wildlife Service's national monitoring protocol (USFWS 2003). Hence, several survey approaches are available.

3.3.1 Annual surveys

Annual surveys of all sites would be conducted, and inventories made of potential cliffs throughout the monument. This approach would provide the most valuable biological information for the assessment, management, and protection of peregrines within Dinosaur NM. However, this would require two teams of observers and use the most resources. Expenditures could be halved by utilizing a single team that visited half the sites one year and the remaining sites in alternate years. This would increase the chance of retaining competent, experienced observers in subsequent years, but would essentially yield alternate-year surveys.

3.3.2 Alternate year surveys

Teams of two observers would be fielded every other year. This survey interval is probably not as effective at tracking occupancy and productivity trends as annual monitoring. However, occupancy and reproductive trends should be relatively obvious and if a sudden decline occurs, the surveys will detect it within two years. In addition to loss of accuracy, there would be attrition of experienced seasonal observers who may have obtained other work in alternate years. It would also be difficult to maintain alternate-year funding spikes within the park unless the funding was alternated with another park.

3.3.3 Three-year surveys

Upon removal of the peregrine falcon from the endangered species list, the U.S. Fish and Wildlife Service implemented a national monitoring protocol (USFWS 2003) that requires visiting a sample of sites every third year over a 13-year period. As with alternate-year surveys, accuracy will be sacrificed and trends in occupancy and productivity will be obscured. A single site (GO) in Dinosaur NM occurs among the sample of 27 monitoring sites designated in Colorado. If the CDW does not implement statewide surveys on annual or alternate years, it is likely the monitoring will only occur on the three-year schedule prescribed by the USFWS. It is probably appropriate for Dinosaur NM to implement more intensive surveys (including GO) on the same schedule.

However, the CDW cautioned the USFWS that a three-year interval would yield only five measurement periods and not be sufficient to adequately detect occupancy and productivity trends. If a catastrophic decline in reproduction occurred, it is possible that two years would pass before anyone was in the field again to detect it. Other concerns would be attrition of expertise and difficulty obtaining funding at such intervals (annual budgets are durable and not forgotten). The same problems will occur with Dinosaur NM—finding funding every three years will be difficult and

experienced seasonal peregrine observers may have found other employment. The USFWS national monitoring program was completed in 2015 and is unlikely to be renewed.

Although index areas had not been established at time of writing, we endorse the annual survey protocol formulated by the Northern Colorado Plateau Network (Daw et al. 2006). However, in addition to regularly monitoring the index sites, the provision for annually surveying suitable nest cliffs at one-mile intervals throughout Dinosaur NM will not be feasible because potential escarpments are not continuous along the river systems. Remoteness and staffing limitations also come into play. It should be possible to select the 6–8 most probable sites that could be inventoried from the river during a multiday float trip. However, as stated previously, visiting only previously known territories is misleading and any population expansion will not be noticed. An additional float trip should be undertaken to inventory other potential cliffs in the system. It is good that the protocol does recognize the advantages of annual surveys, and the program may be able to coordinate funding among the region's parks for its implementation.

3.4 Survey protocol

Survey protocols are detailed in Appendix 2 and in Daw and others (2006). However, several additional points apply to Dinosaur NM.

Most critically, inexperienced observers inevitably compromise surveys. Misidentification of species, sexes, and ages will occur and behaviors will be missed or misunderstood, all resulting in frustration and erroneous conclusions. It is imperative that first-time observers be paired with an experienced party to be mentored during their first season. First-time observers who have gained experience observing peregrines elsewhere should be accompanied to the field and critiqued initially and periodically through the season to ensure Dinosaur NM's survey protocols are being achieved.

Sites should be visited to optimize sunlight on the cliff faces. East-facing cliffs should be viewed in the morning and west-facing sites should be observed in the afternoon. In addition to improved lighting, shadows cast by flying falcons are often seen before the bird is spotted.

Due to lengthy travel time within the monument, observers should plan to camp overnight in the field rather than spend valuable daylight traveling to and from headquarters. This ensures they are present on site early and late in the day, when the falcons are often active.

3.5 Whole egg and eggshell collection

Thickness of whole eggs and contaminants in egg contents provide valuable insight into pesticide contaminant trends. Contaminants within egg contents are the most accurate measure of body-burden levels and a single egg is usually representative of the entire clutch (Craig and Enderson 2004). However, a concerted effort must be made to collect a valid sample of eggs throughout the region, to be handled and analyzed according to USFWS laboratory protocols. A statistically significant random sample of nest sites should be visited during incubation and a single random egg removed for analysis. These collections will likely be controversial because viable eggs are removed and productivity will be reduced. However, if only dead or infertile eggs are collected after the young have fledged, bias is introduced because they may have failed due to abnormally thin shells or high pesticide loading. In addition to being controversial, egg-collection is labor-intensive and expensive. Egg collections scheduled every 10 years should provide adequate trend information.

Although not statistically relevant, any abandoned eggs that are encountered serendipitously should be collected, measured, and analyzed. However, it may be difficult to have them analyzed. Chlorinated hydrocarbon pesticide scans are complicated and expensive (exceeding $300 per sample assayed) and must be submitted to a USFWS-approved laboratory to ensure comparability with previous analyses. Contact the chemical contaminant specialist with the U.S. Fish and Wildlife Service in the regional office regarding disposition and analysis of such eggs.

Craig and Enderson (2004) found that while a single egg from a clutch adequately represented the residue levels within the entire clutch, the eggshell thickness may vary widely among the eggs and did not correlate closely with the pesticide levels. Additionally, shell fragments sifted from nest ledges after the young fledge are even less useful. Fragments from other eggs are often intermixed and can vary significantly from the same egg if they originated from the poles or waist (Craig and Enderson 2004). Eggshells tend to persist longer than egg contents and although measurements are not statistically robust, thicknesses do provide a coarse measure of eggshell condition. Proper protocol for eggshell measurement is provided in Appendix 3.

4 Management Recommendations

4.1 Buffers and closures

Many peregrine nest sites within Dinosaur NM are on remote, undisturbed cliffs and may not require additional measures to protect them from human disturbance. However, past wildfire suppression efforts have necessitated implementing buffers for helicopter overflights at two sites (HS and GL) to protect the nesting efforts. Air crews must also be warned away from cliffs during search-and-rescue operations. Closures and buffers will probably have to be imposed elsewhere as backcountry usage increases and other unforeseen activities are proposed. For example, the San Isabel National Forest recently received a request from an outfitter for permission to lead river trips that originate with clients rappelling over a cliff to the river, then boarding rafts for the whitewater portion of the excursion. A conflict arose when they chose a cliff occupied by peregrines. Remote cliffs to the southwest of the monument are now popular launch sites for hang gliders who may disturb pairs nesting at CE and CW.

4.2 Overflights

Peregrines are generally tolerant of aircraft overflights, unless the activity is so close that it elicits a direct, defensive response or is so persistent that it interferes with the adults' ability to forage for prey. Fixed-wing aircraft rarely fly slow enough or in close enough proximity of cliffs to elicit a response. However, on several occasions when conducting aerial reconnaissance of nest ledges, we encountered unusually defensive adults that attacked the helicopter and were nearly drawn into the rotors. A no-fly buffer area of at least one half-mile should be established around occupied nest cliffs during the breeding season (April 1–July 31). Because of pilots' preoccupations with other duties and wind conditions, it would be advisable to expand the buffers to 0.75 miles to avoid incidental encroachment.

4.3 Closures

Peregrines nesting in the monument have already selected their nests by early spring, prior to the period of high human visitation. Sites that were remote and undisturbed during courtship and ledge selection may be inundated with people after Memorial Day. When human encroachment occurs, peregrines are less tolerant of human activity above their nest than below. The campground at SB is a good example of tolerance of normal campground activities and a seasonal closure is not warranted. The opposite occurs at HS. The cliff tops are easily accessible and human presence usually elicits defensive reactions, especially when the falcons nest near the top of the escarpment. A closure from April 1 through July 31 is clearly required—in part, for visitor safety. When a closure must be violated, trained observers should be present to monitor the falcons' reactions and require withdrawal when necessary.

Although rock climbing is not a high-use activity in the monument, sandstone climbing enjoyed brief popularity in the late 1960s. If there is a resurgence, climbing closures should be implemented on all faces within one half-mile of active nest ledges. When activated, closures should extend from April 1 through July 31.

4.4 Illegal harvest

In past years, the monument's peregrines were protected by their endangered status and their extremely small numbers scattered throughout the expanse of potential nest sites. Although most sites are on nearly inaccessible escarpments that require technical rock climbing skills, nestlings have been vulnerable to prolonged disturbance or illegal take several times. Disturbance of nesting pairs has occurred, but illegal harvest of peregrines has not been documented in Dinosaur NM. Captive propagation of peregrines has partially met the demand by the falconry community for wild stock. However, the U.S. Fish and Wildlife Service recently promulgated rules permitting harvest of wild nestlings and illegal attention may be focused on easily accessible sites within the parks and monuments in the future.

Anonymity of nesting sites is the best and most economical deterrent to shooting, harassment, and illegal take. Nest locations should be treated as a sensitive resource similar to archeological sites and only provided on a need-to-know basis.

Peregrines do nest on cliffs in the vicinity of several campgrounds and their presence is public knowledge. The presence of other campers should discourage harassment and illegal take and no extraordinary steps need be taken. Should sites become vulnerable, it may be necessary to specifically patrol the area and post observers to apprehend or turn away violators. The period of protection may have to extend from initiation of egg-laying through fledge (April–July). Although it may be possible to utilize volunteers, the effort will be intensive and impact the monument's personnel resources.

5 Conclusions

So what are the implications for peregrine falcon populations? First, the threat related to DDT use has not been removed; it is listed as an impurity in dicofols (Kelthane), and calls are made to apply it for mosquito-borne diseases. New chemicals, pathogens, or diseases (e.g., West Nile virus, fowl cholera, and avian influenza) might cause a population decline. Most monitoring programs currently in use (post-delisting) look only at site occupancy, which is not sensitive to population fluctuation. A statistical subset of the survey sites should also be examined for productivity to detect possible reproductive declines. Finally, as the population expands and Dinosaur NM approaches carrying capacity, marginal sites will be occupied last, probably intermittently. They will also be first to become and remain vacant should the population decline. Locating and surveying marginal sites will improve the sensitivity of the monitoring program.

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Appendix 1. Site Histories

AH: AH was inventoried in 1981 and 1982, then later in 1985 and 1986, before peregrines were found in 1987. Therefore, intermittent occupancy information for AH began in 1981 and not at the time of the discovery of the falcons in 1987. Subsequent eyries have been recorded on both sides of the Yampa River.

BJ: Falcons were discovered at BJ in 1989, but the occupancy record began 11 years earlier (1978), when the cliffs were first surveyed during a river trip. Since 1989, eyries have been on both sides of the river, but spread over a distance of nearly 0.75 mile.

CE: A pair of nesting peregrines was confirmed at this site in 2002, after following up a report by hang gliders that peregrines were seen from the rim in 2001. Although the area abounds with large cliffs that dominate the region, it had not been surveyed for peregrines due to its remoteness and discontinuity with the monument. Length of occupancy is unknown.

CW: This site was discovered in 2004, when surveys were expanded to include potential cliffs adjacent to the CE site. As with CE, no previous surveys had been conducted and a history of occupancy is unknown.

GL: Clayton White reported that he had seen a pair of peregrines at these cliffs in the early 1960s. The history of occupancy thus begins in the 1960s for GL, but it was vacant when first surveyed in 1975. The cliffs were surveyed almost annually since that date, and a pair was finally discovered on territory in 1989, after at least 14 years of vacancy. All known eyries have been situated on the west side of the Green River.

GO: GO was vacant when first surveyed in 1977, so the history of this site begins in that year. It was also vacant when visits were made in 1978 and 1981. A breeding pair was first recorded in 1984. All known eyries have been located on the south side of the Yampa River.

HA: In 1980, a hack site was operated near this location, but it was discontinued because of the potential for predation by great horned owls. The cliffs were surveyed annually, and found to be vacant until 2004, when a nesting pair occupied the site. The history of this site begins in 1980 when it was first surveyed. All known eyries have been located on the south side of the Yampa River.

HS: The history of this site begins in 1977, when a pair of peregrines with two young was reported by a Fish and Wildlife Service employee. No surveys had been conducted in the area prior to 1977, although there is an old report in park files of peregrines on the site in 1957. The site may have been occupied for several years prior to 1977. Known eyries have all been on the south side of the Yampa River, but spread over a distance on nearly 0.75 mile, with the westernmost eyries in a side canyon.

JH: Reports of peregrines at JH were received and investigated in 1981, but occupancy was not confirmed until eight years later (1989). Falcons undoubtedly were present earlier, but intermittent searches were often confined to the vicinity of the Green River rather than upstream along the side drainage where the site was eventually confirmed. Therefore, 1989 was assigned as the year of discovery for JH. All known eyries have been located in the side drainage area.

OP: OP was visited and found vacant in 1983. Therefore, the history of this site started in 1983. It was revisited four years later (1986) and again was vacant. The following year (1987) OP was occupied by an adult male peregrine paired with a prairie falcon. In 1988 OP was occupied by a yearling peregrine tiercel and an albino prairie falcon; both were present the next year. Since occupation was discovered, eyries have been located both near the initial discov-

ery area and downstream around a major bend in the Yampa River canyon. These latter eyries were nearly 2 miles downriver, but only about 1 mile in direct line distance.

PC: PC was checked fairly thoroughly in 1981 and reported vacant. Therefore, the history for PC starts in 1981. Rechecks were not adequate over the intervening eight years. In 1988, peregrines were observed from across the river during management of a wildland fire. Occupancy may have occurred in 1988 or earlier, but was not confirmed until 1991. All known eyries have been situated on the west side of the Green River.

RB: The history of this site started in 1981, when it was first surveyed, but was vacant. It was resurveyed in 1984, and was again recorded as vacant. The cliffs were not surveyed again until 1991, when peregrines were found on territory. The first year of occupancy is unknown because RB had not been checked the previous seven years. All known eyries have been situated on the west side of the Green River.

RP: RP was first inventoried in 1987 and 1988, and found to be vacant during both years; thus the history of this site begins in 1987. It was not revisited until 1994 when breeding peregrines were observed. Because it was not checked in the intervening six years, the date of first occupancy cannot be established. All known eyries have been located on the east side of the Green River. Because of the local topography (it must be viewed from above), actual eyrie sites have been very difficult to identify.

SB: Bird watchers knew of this site in the 1960s, but their reports lacked many important details. The history of occupancy thus begins in the 1960s for SB. When we visited the site in 1972, a pair of courting peregrines was observed. Aside from vacancies from 1984 through 1986, the site has been continuously occupied. Known and suspected eyries have been scattered throughout the area on north-, south-, east-, and west-facing cliffs, even as far upstream on the Green River as 0.75 mile from the traditional territory.

SC: SC was first documented when breeding peregrines were observed in 1991. Although the history of this site begins in 1991, it could have been occupied in previous years since no inventories were conducted in the area. Known eyries have been located on both sides of the Green River, with separation of eyrie locations as much as 0.75 mile.

SM: Hacking operations were initiated at this site 1984 and continued through 1988. A pair of adult peregrines was recorded on the territory from 1990 through 1992, but actual nest ledges were not confirmed. Breeding peregrines have not been documented since 1992. The appearance of wild adult and subadult peregrines at the hack site suggests this territory may have been active in the mid 1980s. The site is extremely difficult to observe. It is possible that occupancy has continued since the mid 1980s. Most observed activity on the territory has been on the east side of the Green River.

TG: This site was vacant when first surveyed in 1984. It was not adequately checked again until 1994, when a pair of peregrines was observed. Although a pair was again seen in 1995, actual nest ledges were not confirmed during either year. Peregrines were not observed again until a pair was seen in 2004; once again, a nest ledge was not confirmed. This may be a situation of missed opportunities since visits through the years were inconsistent and too brief. Observers did not diligently survey all potential cliffs in the area, and it is possible a nesting pair was simply missed. If competent surveys in the future yield a breeding pair of peregrines, the history of this site should begin in 1984. All recorded activity centered on the south side of the Yampa River.

XM: Although this site is on Bureau of Land Management lands, it is immediately adjacent to monument's east boundary and was incorporated the survey. Although observers in a 1981 helicopter survey of XM thought they saw a peregrine scrape, the evidence was insufficient to reach a conclusion, especially since prairie falcons were observed in the area. Sightings of

a subadult peregrine, and later an adult peregrine, then a pair near the mouth of the XM canyon in 1984, led to a minimal survey of XM, which did not confirm presence of peregrines. The site was not revisited for two years, then occupancy was confirmed in 1987. The discovery date of 1984 was assigned to this site and it was considered vacant, although ancillary observations suggest a pair may have been present several years earlier. Subsequent to discovery, eyries have been located on both sides of the Yampa River.

Table A-1. Occupancy of peregrine falcon sites in Dinosaur National Monument, 1972–2004.

Year	AH	BJ	CE	CW	GL	GO	HA	HR HS	JH	OP	PC	RB RI	RP	SB	SC	SM	TG	XM	Occupied	Vacant	Not checked
1972	–	–	–	–	–	–	–	–	–	–	–	–	–	occ	–	–	–	–	1	0	0
1973	–	–	–	–	–	–	–	–	–	–	–	–	–	occ	–	–	–	–	1	0	0
1974	–	–	–	–	–	–	–	–	–	–	–	–	–	occ	–	–	–	–	1	0	0
1975	–	–	–	–	–	–	–	–	–	–	–	–	–	occ	–	–	–	–	1	0	0
1976	–	–	–	–	–	–	–	–	–	–	–	–	–	occ	–	–	–	–	1	0	0
1977	–	–	–	–	–	vac	–	occ	–	–	–	–	–	occ	–	–	–	–	2	1	0
1978	–	vac	–	–	–	vac	–	occ	–	–	–	–	–	occ	–	–	–	–	2	2	0
1979	–	n.c.	–	–	–	n.c.	–	occ	–	–	–	–	–	occ	–	–	–	–	2	0	2
1980	vac	vac.	–	–	–	n.c.	–	occ	–	–	–	–	–	occ	–	–	–	–	2	3	1
1981	vac	n.c.	–	–	vac	vac	vac	occ	–	vac	vac	vac	–	occ	–	–	–	vac	2	8	1
1982	vac	n.c.	–	–	vac	n.c.	vac	occ	vac	vac	n.c.	n.c.	–	occ	–	–	–	n.c.	2	5	5
1983	n.c.	n.c.	–	–	n.c.	n.c.	vac	occ	n.c.	vac	n.c.	n.c.	–	occ	–	–	–	n.c.	2	2	8
1984	vac	vac.	–	–	vac	occ	vac	occ	vac	vac	vac	vac	–	vac	–	vac	vac	vac	2	12	0
1985	vac	vac	–	–	vac	occ	vac	occ	n.c.	n.c.	n.c.	n.c.	–	vac	–	vac	n.c.	n.c.	2	6	6
1986	vac	n.c.	–	–	vac	occ	vac	occ	n.c.	n.c.	n.c.	n.c.	–	vac	–	n.c.	n.c.	n.c.	2	4	8
1987	occ	vac	–	–	n.c.	occ	vac	occ	n.c.	vac	n.c.	n.c.	vac	occ	–	n.c.	n.c.	occ	5	4	6
1988	occ	vac	–	–	vac	occ	vac	occ	n.c.	occ	n.c.	n.c.	vac	occ	–	n.c.	n.c.	occ	6	4	5
1989	occ	occ	–	–	occ	occ	vac	occ	occ	occ	n.c.	n.c.	n.c.	occ	–	n.c.	n.c.	occ	9	1	5
1990	occ	occ	–	–	occ	occ	vac	occ	occ	vac	n.c.	n.c.	n.c.	occ	–	occ	n.c.	occ	9	2	4
1991	occ	occ	–	–	occ	occ	vac	occ	occ	occ	occ	occ	n.c.	occ	–	occ	n.c.	occ	13	1	2
1992	occ	occ	–	–	occ	occ	vac	occ	occ	occ	occ	occ	n.c.	occ	vac	occ	n.c.	occ	12	2	2
1993	occ	occ	–	–	occ	occ	vac	occ	occ	occ	n.c.	occ	n.c.	occ	vac	n.c.	n.c.	occ	10	2	4
1994	occ	occ	–	–	occ	occ	vac	occ	occ	occ	vac	occ	occ	occ	occ	vac	occ	occ	13	3	0
1995	occ	occ	–	–	occ	occ	vac	occ	occ	occ	n.c.	occ	occ	occ	vac	vac	occ	occ	12	3	1
1996	occ	occ	–	–	occ	occ	vac	occ	occ	occ	occ	occ	occ	occ	occ	n.c.	vac	occ	13	2	1
1997	occ	occ	–	–	occ	occ	vac	occ	occ	occ	n.c.	occ	occ	occ	occ	occ	vac	occ	13	2	1
1998	occ	occ	–	–	occ	occ	vac	occ	occ	occ	occ	vac	occ	occ	occ	n.c.	n.c.	occ	13	1	2
1999	occ	occ	–	–	occ	occ	vac	occ	occ	occ	occ	occ	occ	occ	occ	n.c.	n.c.	occ	12	2	2
2000	occ	occ	–	–	occ	occ	vac	occ	occ	occ	occ	n.c.	occ	occ	occ	n.c.	vac	occ	12	2	2
2001	occ	occ	occ	–	occ	occ	vac	occ	occ	vac	occ	n.c.	occ	occ	occ	vac	vac	occ	12	4	1
2002	occ	occ	occ	–	occ	occ	vac	occ	occ	vac	occ	vac	occ	occ	occ	vac	vac	occ	12	5	0
2003	occ	occ	occ	–	occ	occ	vac	occ	occ	occ	occ	vac	occ	occ	occ	vac	vac	occ	13	4	0
2004	occ	occ	occ	occ	occ	occ	occ	occ	occ	occ	occ	vac	occ	occ	vac	vac	occ	occ	15	3	0

occ = occupied; vac = vacant; n.c. = not checked. Bold=first recorded year of occupancy. Years with "occ" are also shaded green.

Appendix 2. Field Procedures (adapted from Craig and Enderson 2004)

Surveys for Breeding Peregrines

Searches for breeding peregrines required hours of tedious scanning with binoculars and spotting scopes at distant cliffs. The monotony was sometimes interspersed with moments of charged tension caused by the brief sighting of a flying falcon. Sometimes the bird vanished at a critical point. The purpose of field observations was to document behaviors associated with a particular stage of the reproductive cycle. Once the stage of reproduction was determined, dates of hatch and fledge were estimated so that the observers could return at appropriate dates to count young and document fledge.

The monitoring protocol we used was refined over several decades of surveying cliffs and observing breeding peregrines. We used the following procedures when surveying for peregrines or monitoring occupancy and reproductive success.

Field Teams

Although a single, experienced observer can accomplish the job, we usually sent teams of two people to observe peregrines. A team should comprise at least one member skilled in raptor identification and knowledgeable of peregrine breeding behaviors. The subordinate member, if inexperienced, must be patient, a good observer, and willing to learn. Excellent eyesight and hearing are mandatory because of the long distances and faint vocalizations of falcon behaviors. Observers must be able to identify all raptor species where they are working. Valuable insight can be gained by tracking the activities of various raptors that come into view. For example, accipiters rarely draw the attention of peregrines while eagles almost always elicit a vigorous defense. Observers must be able to distinguish prairie falcons and peregrines. Failure in that regard can waste valuable field time. When inexperienced teams were able to observe the nest ledge, they were encouraged to continue to watch the behaviors to gain experience seeing the activity that was ordinarily out of their view.

Team members usually remained together and observed simultaneously. When falcons were in view both members remained vigilant to track flights and follow each bird. When a pair was present each team member kept track of one adult. On occasion, one member relieved the other as notes were taken or lunch prepared. If the team was experienced, the members split up for short intervals to view the cliffs from advantageous observation points. In these situations, radio communication was essential.

Sometimes observation points were more than 0.5 mi from nest cliffs. Eyrie ledges were often hidden from view in canyons and mountain sides. In these cases, the observers relied on inferences drawn from activities and behaviors of the falcons. When behaviors associated with a particular reproductive activity were not evident to the field observers, it was helpful for them to compare notes and speculate on what they observed. Several visits were sometimes necessary before a pattern of activities emerged. If the reproductive stage was not defined, field notes were read to an experienced biologist. Therefore, it was critical that each observer independently recorded detailed field notes.

As teams gained experience, the length of visits was often reduced. However, the team did not terminate their observations until both members were satisfied further watching was unwarranted. As a guide, field teams watched for a minimum of four hours at each visit to a territory.

Field Notes and Photographs

We found that field observations written in narrative fashion were most effective. Each observation was preceded by the time it occurred. Notes included sketches of each cliff that identified key features such as important perches, prey caches and nest ledges. Notes provided a brief summary including total duration of observations, presence or absence of each adult, reproductive stage, presence of bands or markers, and other biologically important occurrences. Daily notes were duplicated and filed, avoiding loss or destruction.

Photographs of each site included a distant view of the cliff, a normal view from the observation point and when possible, telephoto images of each nest ledge. Photographs were usually taken on the first visit so that important features could be transcribed on them in subsequent visits. We experimented with instant Polaroid cameras but these photographs often lacked detail and were difficult to reproduce. Digital technology was not available in the early years of monitoring, and still lacked adequate resolution during the last years of our involvement. We found that the best photos were glossy color prints made from 35 mm slide or print film. These offered the best reproduction and enlargement quality.

Use of Optical Equipment

A high quality spotting scope is indispensable. The larger objective lenses (60mm and more) provide better lighting. Zoom oculars are an advantage, although magnifications over 40x are rarely used due to loss of light and resolution. We generally scanned cliffs at 15–20x and zoomed to higher powers to identify birds or monitor their behaviors. Binoculars with 10x magnification were essential for scanning to locate falcons. A sturdy tripod was necessary to stabilize spotting scopes or binoculars. The tripod should accept interchangeable heads. A "fluid" with a friction adjustment aids in tracking a flying peregrine. Lightweight aluminum folding chairs and portable sling chairs make viewing more comfortable.

Visits to Nest Sites

Observations were made at any time of day. Early morning and late afternoon observations tended to be productive since peregrines were active (incubation exchanges and hunting forays) at those times. However, we found that activity also increases at midday when prey and incubation exchanges occurred.

East-facing cliffs were best viewed in the morning to avoid backlighting and glare in the optics. For the same reasons, we sought to observe west-facing cliffs in the afternoon. Obviously, rain and snow storms reduced visibility. High winds did not seem to affect peregrine activity. However, buffeting can make it impossible to view through spotting scopes.

Teams documented presence of both adults, checked for presence of bands or markers, and noted ages and plumage patterns for future reference. Facial color pattern was very important because individuals were often distinct. Observers tried to reaffirm that the same individual falcons were present on each visit. Helmet patterns (placement of narrow or wide cheek stripes) were often individualized and do not change from year to year (Enderson and Craig 1988). A change in the plumage of an individual on a subsequent visit meant replacement and probable interruption of the nesting sequence. Pairs with a subadult member rarely produced young. In Colorado, only two subadult females produced young, while no pairings with subadult males were successful. Subadult plumages were more evident early in the spring but tended to be more difficult to distinguish from adult plumage as the molt progressed.

Once the reproductive stage was known, a visit was scheduled to confirm the next reproductive event. The team then moved on to the next site. However, if the exact onset of the event could not be determined from observations, the team returned within a reasonable period (usually 10–14 days) to reaffirm their prediction. We estimated the timing of reproductive

events using the following factors: Eggs were laid about every other day. Full-time incubation occurred upon clutch completion (up to 4 eggs per clutch) and required about 33 days. Hatching occurred over 1 to 2 days and fledging occurred at 40 days of age (males) and 42 days of age (females).

The number of visits made to a site depended upon the information to be obtained. Documentation of occupancy (presence of adults) could often be accomplished with a single visit. However a return visit was required for confirmation if no falcons were seen on the first visit. Occupancy was ascertained early in the breeding season during courtship or incubation. Later visits tended to undercount occupancy since unsuccessful pairs may abandon territories after failure. Complete documentation of nesting through fledging required up to four visits. The first was made during courtship to locate pairs when they are displaying and most active. A second visit was made to locate potential nest ledges or confirm incubating adults. Depending upon the stage of reproduction observed on the second visit, a third visit was scheduled to confirm that young hatched. The final visit occurred at fledging, based upon estimated ages of the young present on the third visit. When chick ages were not known, an interim visit was required when the young were likely to be seen moving about the ledge (three to four weeks) so that a fledging date could be estimated.

An estimate of observer hours required to monitor sites can be developed from personnel time expended during the 2000 and 2001 Colorado statewide inventories. Collectively 511 visits were made to 278 nesting pairs and the teams devoted 1,470 hours of observation of breeding peregrines. Hence, the field teams averaged 1.8 visits per site and spent about 3 hours in observation per visit to document presence of breeding falcons. In most cases, territory occupancy was confirmed in the first visit. During the same period, 40 additional sites were monitored more closely to confirm fledging success. These sites averaged 4.5 visits and 3.26 hours of observation per visit. The number of visits ranged from 1 to 8 and hours of observation expended per visit ranged from 15 minutes to 8 hours. We believe that teams should plan a minimum of 4 visits to confirm fledgling success. Although serendipitous circumstances may reduce the length of visits, about 4 hours of observation was normal although up to 8 hours of observation may be required on occasion.

When the number of young in the eyrie could be determined, the maximum possible number of flying young was of course known. Unfortunately, counts of nestlings were not usually made. Observers often devoted 6–8 hours to be certain all the fledged young scattered about the cliff were tallied. Over the course of our statewide investigations, we encountered only two clutches of five eggs and no broods exceeded four young. Nestlings were most easily counted immediately prior to fledging since they were conspicuous as they exercised, or converged when prey was delivered. After the first flight they became scattered about the cliff and on the talus and were difficult to locate. Once well on the wing, they were noticeable as they pursued the adults and each other.

Counts made solely several days or weeks after fledging might seem the most economical use of limited observers. However, these counts may underestimate the number of young actually fledged due to early attrition resulting from accidents and predation.

Nesting Behavior Useful in Field Observations

Behaviors of adults were used to understand the status of the nesting attempt. When either or both adults went on a ledge for only several minutes early in the season, nest ledge selection or scrape preparation was suspected. If one adult remained on the ledge for long periods, incubation or brooding was indicated. Both adults assumed roles in these activities and switched places at the nest with a minimum of overlap. The casual observer might have thought only one bird was present, making a quick visit, then leaving; in reality, a nest duty exchange had occurred.

Prior to hatching of eggs, prey was rarely carried to the nest ledge. When prey was transferred to the female in the air, the male usually sought to incubate the eggs. When young were present, prey usually was transferred from the male to the female and then was taken directly to the ledge. Females usually fed small young, but simply dropped off prey when the young were three weeks old or more. Both adults cached excess food in nooks about the cliff and were fully capable of recovering food stored in this way. Sometimes females stopped brooding, flew to a cache, and returned to the ledge to feed young. Large young required lots of food and it was rare for a male to arrive with food without a delivery to the female or the young.

When young were present, the adult female was usually present on the cliff. Females did most of the brooding and incubation. Females will hunt near the cliff locally when young no longer require brooding. Regardless of age of the young, females usually remain on the ledge in inclement weather.

Females repeatedly gave the "wail" call when hungry. A successful male also "wailed" when returning with prey. This call stimulated the females to streak from the ledge to intercept the incoming mate, sometimes a few hundred meters from the cliff. Peregrines gave the "echup, echup" call as a recognition of another adult. We never heard the call by a bird known to be alone and always assumed a pair was present. The defense "cack, cack" vocalization was given by both sexes when eggs or young were present. The presence of other raptors (especially golden eagles), and occasionally the observers, would elicit the call. It would be brief or absent if young or eggs were not present.

Appendix 3. Methods of DDE Analysis and Eggshell Thickness Measurement (adapted from Craig and Enderson 2004)

Whole unhatched eggs and eggshell fragments were collected opportunistically during fostering activities and routine visits to eyries to band nestlings. Fostering involved removing entire sets of eggs before hatching, replacing them with dummy eggs, artificial incubation of the wild eggs, and early rearing of hatched young. Later an entire brood of typically three-week-old young were placed in the eyrie and the dummy eggs removed. Unhatchable eggs were wrapped with acetone-washed foil, and stored frozen. Later the contents were allowed to thaw slightly, the eggshell cut around the equator, and the contents stored frozen in an acetone-washed jar with a foil liner in the lid. The half shells were then rinsed clear of egg contents and dried thoroughly.

Organochlorine Analysis

Organochlorine analyses were accomplished using accepted extraction, cleanup, and GLC techniques by the USFWS laboratory at Patuxent, Maryland; Raltech Scientific Services at Madison, Wisconsin; the Mississippi State Chemical Laboratory under contract to the US-FWS; and Long Marine Laboratory at the University of California, Santa Cruz. Only DDE is considered here because it alone causes significant shell thinning in peregrines (Peakall and Kiff 1988).

Egg contents were shipped frozen on dry ice, but sometimes thawed enroute. DDE amounts are reported here on a fresh wet weight basis. Included in the lab results was percent moisture of the sample tested. That value was used to adjust (usually downward) the reported DDE value to reflect a result had the contents been fresh. We assumed fresh egg contents contain 85% moisture.

Eggshell Measurement

All eggshells were measured optically. The freshly broken shell was viewed edge-on with a microscope using an ocular scale calibrated with a stage micrometer, accurate to 0.004 mm. When shells were sufficiently intact so that the equator could be identified, three thickness measurements were spaced evenly around the waist. These measurements were averaged and considered representative of the whole shell. When more than one such whole shell determination was made in one clutch, the mean values for each were averaged. All eggshells in this report have been archived at The Peregrine Fund, Boise, Idaho.

Usually several fragments were found on each ledge when banding was done. All fragments large enough to handle were measured. The thickness values for all fragments from the same eyrie were averaged. Seldom was it possible to determine the number of eggs represented by fragments from an eyrie. Further, eggshells are several thousandths of a millimeter thinner at the poles compared to the equator. Because our samples of fragments surely contained pieces from the poles, the mean thickness of fragments was probably biased downward.

Sometimes the microscopic examination of whole shells or fragments revealed loss of the shell membrane. We found the mean membrane thickness, measured optically in a large sample of eggshells with membrane intact, was 0.079 mm. Therefore we added that value to shells without a membrane to correct for the loss. Other studies report the use of a membrane correction value as low as 0.063 mm (Monk et al. 1988). Our measurement of the relatively soft membrane was made optically, while other studies usually used mechanical techniques that exert a force on the membrane. The optical technique does not compress the membrane.

Appendix 4. Peregrine Monitoring Personnel, Dinosaur National Monument

This list includes NPS employees, Student Conservation Association interns, other interns, and volunteers identified in field notes. Errors or omissions are entirely mine. —Steve Petersburg

Adams, Elaine 1985–1986
Aho, Travis 2000
Alston, Joe 1976–1977
Askeris, Christi 1989–1990
Ballard, Bert 1992–1993
Barnes, Larry 1984
Bennett, Erin 2004
Bonds, Phil 1991–1994
Brown, Amy 2002
Brown, Mary E. 1991–1993, 1995–1996
Buschkowsky, Jennifer A. (née Diaz) 1998–2002
Butler, Greg 1980–1983
Callard, Mandy 1990
Chambers, Susan 1990–1991, 1994
Chase, Myron 1986–1987
Coleman, Melissa 1992
Collier, Jesse 1996
Collins, Elyssa 2003
Craig, Kelly 1989–1990
Crofts, Kathy 1990
Darby, Mary Claire 1994
Delafield, Hardin 1991–1996
Elder, Mark 1979–1980
Ferrell, Jason 2004
Fiala, Frank 1978, 1980
Fields, Carol Ann 2000
Finnie, Don 1987–1988
Fitzmorris, Ty 1997
Foy, Andrew 2003
Friedlander, Joan 1983–1984
Frederick, Jay 1990
Gangemi, John 1982
Gaylen, Lisa 1995
Girard, Michell 1982
Hetzler, Brent C. 1998
Hogan, Drew 1984–1990
Hogan, Joel 1978–1989
Hogg, Patty 1993
Hughey, Brenda 1999
Kelley, Bill 1984–1985
Knamiller, Peter 2004
Krumenaker, Bob 1982–1983
Kuchel, Michelle 1991
Levine, Rachel 2003
Lieberman, Penny 1993
Liebman, Dana 1987
Loscalzo, Matt 2000
McBrayer, Jim 1982–1983
McDonald, Tina 1990
Moode, Erin 1996
Morgan, Laurie 1985
Moroge, Michael 1995
Munsell, Steve 1981
Naumann, Tamara 1996–2004
Nourne, Rain 1997
O'Neal, Elen 2001
Panchal, Susmita 1998
Papadakos, David 1997–1999, 2002
Petersburg, Mylea 1988–1991
Petersburg, Stephen 1974–2002
Pierce, Sherry 1994
Pilkington, Rupert 1989
Pontbriand, Ed 1994–1997
Poole, Kate 1988
Porterfield, Shelly 1988
Rice, Tamara J. 1994
Riedel, Lynn 1987–1988, 1991, 1994
Robertson, Andy 1989
Ross, Glade 1974–1989
Sas, Christy 1994
Schrader, Patty 1985
Schroeder, Mark 1985–1986
Scotton, Katharine 2004
Siegel, Erin 1995
Skiba, Gary 1981–1983
Skinner, John 2002
Skornicka, Traci 2001
Slater, Matt 2002–2003
Smith, Candice 1996
Smith, Cathy 1985–1986
Sobel, Ann 1995
Spencer, Emily 2003–2004
Sterkel, Mark 1993
Suess, Todd 1991
Terry, Madeline 2001
Unger, Zac 1997
Uriarte, Maria 1993
Vana, Sandy 1981
Van Schmus, Alyssa 1996
Walker, Sharon 1992
Warner, Barbara 1982
Wathen, Steve 1983–1984
Wegner, Eric 1981
Welsh, Michael 2002–2003
Wesley, Gina 1996
Williams, Leslie 1992
Williams, Peter 1996–2004
Wolfe, Gerry 1980–1981
Zeigenfuss, Larry 1991
Zinn, Barbara 1992

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