THE NESTING AND REPRODUCTIVE SUCCESS OF RED-TAILED HAWKS AND RED-SHOULDERED HAWKS IN ORANGE COUNTY, CALIFORNIA, 1973

JAMES W. WILEY[1]
16341 Skymeadow Drive
Placentia, California 92670

This paper describes nesting and reproductive performance of the Red-tailed Hawk (*Buteo jamaicensis*) and the Red-shouldered Hawk (*Buteo lineatus*) in Orange County, California, during 1973. The field work was conducted from January through July 1973, coincidental to a more comprehensive investigation of the biology of the Red-shouldered Hawk.

Several population studies of the Red-tailed Hawk have been carried out in North America: California—Fitch et al. (1946); Wisconsin—Gates (1972), Orians and Kuhlman (1956); New York—Hagar (1957); Michigan and Wyoming—Craighead and Craighead (1956); Alberta—Luttich et al. (1971); and Montana—Seidensticker and Reynolds (1971). Less work has been done on the Red-shouldered Hawk: Maryland—Stewart (1949), Henny et al. (1973); and Michigan—Craighead and Craighead (1956).

THE STUDY AREA

The topography of southeastern Orange County, California, is characterized by chaparral-covered transitional foothills, wooded creek flood plains, and canyons with live oak (*Quercus engelmanii*, *Q. wislizenii*, and *Q. agrifolia*) groves. A general description of the area and its ecology is given by Pequegnat (1944, 1945). California sycamores (*Platanus racemosa*), white alder (*Alnus rhombifolia*), and willows (*Salix* spp.) are the dominant vegetation in the creek bottoms where the majority of the nests were located. Live oak canyons, cliff faces, and *Eucalyptus* windbreaks around citrus groves were also investigated for nesting activity. Several of the larger creek bottoms are routes for heavily traveled highways.

Field work was conducted mainly on a 42,100-acre ranch which produces cattle, citrus, and farm produce. Farmland is planted mostly to small grain and forage crops. The ranch is patrolled daily by a security guard to prevent trespassing. Several other areas in Orange County and adjacent Los Angeles and Riverside counties were less intensively surveyed for nesting raptors as a means of comparison with the population reported on here.

Other raptors nesting on the study area include: Great Horned Owl (*Bubo virginianus*); Long-eared Owl (*Asio otus*); Screech Owl (*Otus asio*); Burrowing Owl (*Speotyto cunicularia*); Barn Owl (*Tyto alba*); Turkey Vulture (*Cathartes aura*); White-tailed Kite (*Elanus leucurus*); Golden Eagle (*Aquila chrysaetos*); Sharp-shinned Hawk (*Accipiter striatus*); Cooper's Hawk (*Accipiter cooperii*); and American Kestrel (*Falco sparverius*). Raptors observed but not found breeding on the study area were: Short-eared Owl (*Asio flammeus*); Swainson's Hawk (*Buteo swainsoni*); and Prairie Falcon (*Falco mexicanus*).

METHODS

Nests were located using the procedure outlined by Craighead and Craighead (1956:195–199). Red-tailed Hawk nests were initially checked for eggs two weeks after an adult was first observed incubating. This allowed time for the clutch to be completed and reduced the chance of desertion by the adults. Nests were again checked approximately three weeks later to determine hatching success and thereafter at about one week intervals to maintain a record of chick survival.

Red-shouldered Hawk nests were checked more frequently as part of an intensive study of this species. When nest-building was nearly complete, a small mirror was placed over each nest to provide data on egg-laying and hatching dates. The mirrors were positioned so that they did not interfere with the birds' activities and so that nests could be checked without climbing the trees. During the first three weeks of incubation, Red-shouldered Hawk nests were checked with binoculars at two- to three-day intervals from a distance of 30–150 m to determine the presence of an incubating adult. Once a week the nests were checked by reading the mirror with binoculars. During the last week of incubation, nests were checked through the mirrors at two- to three-day intervals and finally at daily intervals at hatching time. Once hatching had occurred, nestlings were weighed and measured at regular intervals: seven nests were visited daily, the remainder were checked at three-day intervals. All nests checked daily were in areas greater than one-quarter mile from a public road to reduce the chance that my activities would attract human attention. Extreme care was taken in visiting nests near public roads to avoid exposing such nests to humans. All nest trees of the Red-shouldered Hawk were surrounded with naphthalene crystals to reduce the chance of predation by mammalian predators following my trail to the nests. Although this possibly biased productivity results, it was thought necessary due to the frequency of my visits to nests.

Juveniles of both species were considered fledged when they were first observed to leave the nest and to perch on adjacent branches or trees. The young continued to return to the nest for feeding and roosting at night for some time after fledging. To prevent premature fledging I did not climb any nest trees near fledging time. Beginning approximately 30–35 days after hatching, nests were checked through a spotting scope from nearby trees, hillsides, or canyon rims where possible. By searching the area immediately

[1] Present address: Department of Natural Resources, P.O. Box 5887, Puerta de Tierra, Puerto Rico 00906.

around the nest tree, the color-marked young could be located for several days after fledging and survival thereby determined.

To observe man's influence on raptor nest success the study area was arbitrarily divided into two sections: area A included the land within one-quarter mile of a public road; while area B included only those areas greater than one-quarter mile from a public road. The study area was thus divided prior to initiating field work with the assumption that this would give a reasonable division of human disturbance patterns.

Man-related nest failures or disturbances were determined in part from direct sightings by me or by residents of the area who had been informed of the investigation. The presence of fresh climbing spike scars on a nest tree also indicated disturbance by man. My spike scars were covered with dark paint (which matched the tree color) after each climb to distinguish them from those of others who had climbed the tree. Young hawks missing from a nest tree with fresh spike scars not belonging to me and without evidence of other predation (e.g., mammal hair on bark, scratch marks from claws on tree trunk, blood, or other remains at nest) were placed in a "taken by man" category. Three by five inch cards were attached to the nest trees requesting that persons climbing to the nest contact me. These cards were positioned so that they could not be seen unless the person was at the nest and so that the cards did not disturb the nesting hawks.

Eggshell thickness measurements of Red-shouldered Hawks were made with a Starett dial micrometer with 0.001-mm divisions. Measurements were taken of fragments and whole eggs with dried membranes present.

Clutch size data from egg collectors' records were taken from the collection of the Western Foundation of Vertebrate Zoology (referred to as WFVZ below).

RESULTS AND DISCUSSION

Nesting and reproductive performance of the Red-tailed Hawk. Nest-building by the Red-tailed Hawk was first observed on 10 February 1973. Laying dates ranged from 5 March to 21 April (mean, 21 March); hatching dates ranged from 6 April to 23 May (mean, 23 April); and fledging dates ranged from 16 May to 1 July (mean, 2 June). This gives a mean fledging period of 41 days, which is somewhat less than the 44-day interval observed by Luttich et al. (1971) in Alberta and the 45–46 day period of Fitch et al. (1946) in California. However, the mean fledging period of the present study is biased since early fledging resulted from humans climbing to a minimum of five nests during this period, prematurely flushing the young birds from the nest. The mean fledging period of young from those nests not climbed by man at fledging time was 47 days. The total breeding season spanned 141 days, excluding the post-fledging dependency period.

All paired Red-tailed Hawks observed on the study area tended active nests (nests at which building occurred). No breeding Red-tailed Hawks were observed in juvenile (first-year) plumage, although five single, first-year birds were observed regularly on the study area.

Of 53 Red-tailed Hawk nests, 38 (71.7%) were in sycamores, 9 (17.0%) in oaks, 4 (7.5%) in *Eucalyptus*, and 2 (3.8%) on cliff faces. Sycamores were the most common tall trees growing in the creek bottoms where the majority of the nests were located. I did not attempt to locate every nest in the study area although intensive searches were made in four areas where it is believed all nests were found. Distances between adjacent nests in these intensively searched areas ranged from 150 m to 2.09 km (average, 0.84 km).

No young were fledged from 14 (26.4%) of the 53 nests. Of these failures 4 (28.6%) occurred before or during incubation, while 10 (71.4%) occurred during the nestling period (a nest failure is considered here to be a nest which fledged no young). Of 20 Red-tailed Hawk nests located on that part of the study area within one-quarter mile of a public road (area A), no young were fledged from 12 (60.0%) nests; 3 (25.0%) of these nest failures occurred before or during incubation, while 9 (75.0%) occurred during the nestling period. No young were fledged from 2 (6.1%) of the 33 nests in area B; one nest failure occurred before incubation had begun and one occurred during the nestling period.

The causes of 12 of the 14 nest failures recorded were determined. Land development and farming disturbances near the nests were responsible for two of the failures which occurred before or during incubation (both in area A). The ten remaining failures occurred during the nestling period. Predation of downy chicks by a Common Raven (*Corvus corax*) accounted for one nest failure (area B), while the nine other failures were the result of nestlings being taken by man (all in area A). I observed nestlings being taken by man from three nests. All of the persons involved were teenagers securing birds for falconry. Persons residing or working in the area observed young being taken from three nests and later reported this to me. Subsequent checks of the nest trees showed fresh spike scars which were not mine. One man-caused nest failure was determined from a response to one of the cards posted on the nest tree. Two nests had the young disappear without anyone observing the act of predation, although fresh spike marks on the tree indicated man was responsible (both in area A).

TABLE 1. Red-tailed Hawk productivity in Orange County, California, 1973.

	Area		
	A + B	A	B
	per nest attempt	per nest attempt	per nest attempt
Status	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
Clutch size	2.53 ± 0.77	2.70 ± 0.86	2.42 ± 0.71
Newly hatched chicks	2.19 ± 0.94	2.20 ± 1.06	2.18 ± 0.88
Large downy young	1.92 ± 1.07	1.65 ± 1.31	2.09 ± 0.88
Fledged	1.64 ± 1.18	0.95 ± 1.23	2.06 ± 0.93

The mean clutch size of 53 active Red-tailed Hawk nests (including two nests which were deserted before egg-laying) was 2.53 (table 1): 22 nests with 2 eggs, 26 with 3, and 3 with 4. Unhatched eggs were found in 4 nests containing 2 eggs, 4 containing 3, and 2 containing 4. Henny and Wight (1970) gave the mean clutch size of the Red-tailed Hawk as 2.92 for California. My analysis of 302 Red-tailed Hawk clutches (WFVZ) collected in California between 1885 and 1961 showed a mean of 3.05 ± 0.68 eggs per nest. This differs significantly ($P < 0.001$) from the mean clutch size (2.63 for 51 nests which held eggs) in Orange County for 1973. However, a bias might be introduced into such calculations by using egg collection data as collectors may have been selecting for larger clutches.

Mean initial brood size was 2.19 nestlings per breeding pair for the entire study area. The hatching success of area A (2.20) was not found to be significantly different ($P > 0.05$) from that of area B (2.18). Hatchability for nests which eventually produced chicks showed a 8.4% egg deficit. Craighead and Craighead (1956: table 46) observed a 0% and 40% egg deficit on their Michigan study area and a 9% loss in Wyoming for the Red-tailed Hawk, while Luttich et al. (1971) reported 4% of the eggs failed to hatch from nests producing young in Alberta. Subsequent loss of chicks up to fledging gives a mean of 1.64 young fledged per nesting attempt in 1973. Fledging success of area B (2.06 per nest attempt) was significantly higher ($P < 0.001$) than that observed on area A (0.95 per nest attempt) primarily due to many nests having all chicks taken from them by man in area A. Robbing of Red-tailed Hawk nests by man was an all-or-nothing situation, with 100% of the chicks being taken from all of the nests which were harvested (accounting for 25 nestlings). This reduced the net fledging success of area A considerably.

The number of young per successful nest which reached bandable size was used by Henny and Wight (1970) as an index to the fledging rate for the Red-tailed Hawk. Their data showed a mean of 2.28 chicks banded per nest in California although this is most likely an overestimate since some mortality between the banding date and actual fledging is probable. The fledging rate derived by Henny and Wight is somewhat higher than the number of young fledged per successful nest (0.95 fledged per successful nest in area A; 2.06 fledged per successful nest in area B) in both divisions of the Orange County study area.

Overall nest success on the Orange County study area was 73.6%, whereas it was 40.0% in area A and 93.9% in area B. Fitch et al. (1946) found a nesting success of 56% in their California Red-tailed Hawk study although they felt this figure was biased low due to nest disturbance. Other reports of nest success range from 50% for south-central Montana (Seidensticker and Reynolds 1971) to 74% for Wisconsin (Orians and Kuhlman 1956).

Nesting and reproductive performance of the Red-shouldered Hawk. Nest-building by the Red-shouldered Hawk was first observed on 2 February 1973. Laying dates ranged from 8 March to 17 April (mean, 24 March); hatching dates from 9 April to 19 May (mean, 25 April); brood departure dates from 20 May to 1 July (mean, 2 June). The average nestling period of the Red-shouldered Hawk was 39 days although this figure is biased low due to early fledging occurring at several nests which were disturbed by man. The mean fledging period of nests which were not thought to have been climbed at fledging time was 45 days. The total breeding season for the Red-shouldered Hawk spanned 150 days excluding post-fledging dependency.

No non-nesting Red-shouldered Hawk pairs were observed on the study area. All nesting attempts by Red-shouldered Hawks observed during 1973 produced eggs. Three (10.3%) of

TABLE 2. Red-shouldered Hawk productivity in Orange County, California, 1973.

	Area		
	A + B	A	B
	per nest attempt	per nest attempt	per nest attempt
Status	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
Clutch size	2.69 ± 0.54	2.67 ± 0.59	2.73 ± 0.47
Newly hatched chicks	2.07 ± 1.03	2.11 ± 1.13	2.00 ± 0.89
Large downy young	2.03 ± 1.02	2.06 ± 1.11	2.00 ± 0.89
Fledged	1.34 ± 1.14	1.06 ± 1.11	1.82 ± 1.08

the Red-shouldered Hawk nests under observation had females in their first-year plumage; the males of these pairs were in adult plumage. Two of the juvenile female nests were successful in fledging young. Although it is generally believed that Red-shouldered Hawks normally breed for the first time in their second year (Henny 1972), Henny et al. (1973) observed one female (of 74 breeding pairs) nesting in juvenile plumage in Maryland.

Of 29 nests used by Red-shouldered Hawks 16 (55.2%) were in sycamores, 9 (31.0%) in oaks, 2 (6.9%) in *Eucalyptus*, and 2 in white alders. The Red-shouldered Hawks consistently nested close to permanent or seasonal water, with no nest trees found farther than 23 m from a creek bed. I attempted to locate all Red-shouldered Hawk nests in the larger creek bottoms, although no estimate of the total population can be made. Distances between adjacent nests ranged from 0.37 to 1.27 km (average, 0.66 km) in the creek bottoms.

No birds were fledged from 10 (34.5%) of the Red-shouldered Hawk nests; of these nest failures, two (20.0%) occurred before or during incubation, while eight (80.0%) occurred during the nestling period. Reproductive success of Red-shouldered Hawks nesting in area A was less than that of pairs nesting in area B. In area A no young were fledged from 8 (44.4%) of 18 nests. Of the nest failures in area A, two (25.0%) occurred before or during incubation, while six (75.0%) occurred during the nestling period. No birds were fledged from 2 (18.2%) of the 11 nests in area B. Both of these failures occurred during the nestling period.

Human activity was the principal cause of nest failures in the Red-shouldered Hawk population, accounting for seven (70.0%) of the failures during the study. One of these man-related failures resulted from farming disturbances to a nesting pair during early incubation (area A). Another nest was deserted during incubation as a result of human activity at the nest (area A). This failure occurred during the first week of incubation when teenagers nailed wooden steps to the nest tree as a means to get to the nest. The adult did not return the next day. Five other nest failures resulted from disturbances by man during the nestling period (all in area B). One nest had all the young taken from it by persons who were observed in the act and interviewed there. The nestlings were taken for falconry. Two man-caused nest failures were determined when the persons involved, responding to the cards posted on the nest trees, confirmed that they had taken the nestlings for use in falconry. Two nest failures were attributed to man after fresh spike scars were found on one nest tree and a deserted rope ladder at the other. One nest failed as a result of high winds dislodging the nest and dumping the 2-week-old nestlings to the ground. The other two nest failures were attributed to Great Horned Owl predation.

Clutch size at 29 nests averaged 2.69 (table 2): 1 nest with 1 egg, 7 with 2, and 21 with 3. Single unhatched eggs were found in one nest containing two eggs and seven containing three. Analysis of 322 Red-shouldered Hawk clutches (WFVZ) collected in southern California between 1880 and 1961 (majority before 1928) showed a mean of 3.08 ± 0.65 eggs per clutch which differs significantly ($P < 0.001$) from the observed mean clutch size for the 1973 southern California sample. Henny (1972), using previously unpublished data collected prior to 1930 for the most part, gave the mean clutch size of California Red-shouldered Hawks as 3.30 ± 0.73.

Mean initial brood size for the Red-shouldered Hawk was 2.07 chicks per breeding attempt for the total study area. The hatching success of area A (2.11) was not significantly different from that of area B (2.00). Hatchability at nests which eventually held young showed a 8.9% loss of eggs. This is similar to the egg deficit which I observed for the Red-tailed Hawk (8.4%) on the study area. Craig-

TABLE 3. Eggshell thickness data for Red-shouldered Hawk, Orange County, California, 1973.

Sample	n	Mean (mm)	% change since pre-1947[a]	Range
Pre-1947 western U.S. (Anderson and Hickey 1972)	61	0.367		—
Orange County, California, 1973	31	0.314	–13.9%	0.279–0.364

[a] Percent difference from pre-1947 eggshell thickness data given in Anderson and Hickey (1972) for the western United States.

TABLE 4. Eggshell thickness on the basis of hatching success for Red-shouldered Hawk, Orange County, California, 1973.

Clutch status	n	Mean (mm)	% change since pre-1947[a]	Range
Clutches without unhatched eggs	18	0.331	– 9.8%	0.297–0.364
Clutches with unhatched eggs	10	0.287	–21.8%	0.279–0.297

[a] Percent difference from pre-1947 eggshell thickness data given in Anderson and Hickey (1972) for the western United States.

head and Craighead (1956: table 46) reported a 19% and 36% egg deficit due to destruction, infertility, and failure to hatch in their Michigan study of the Red-shouldered Hawk.

Fledging success for the combined study areas showed a mean of 1.34 young fledged per nesting attempt (2.05 fledged per successful nest). Fledging success on area A (1.06 young per nesting attempt; 1.90 young per successful nest) was somewhat lower, though not significantly so ($0.08 > P > 0.05$), than that of area B (1.82 young per nesting attempt; 2.22 per successful nest).

Henny (1972) again used the number of young which reached banding age per successful nest as an index to the fledging rate. His data indicated a decline of the fledging rate of the Red-shouldered Hawk in the time period of 1946–68 when compared with the pre-1946 fledging rates. The data showed a mean of 2.25 chicks banded per successful nest in California after 1945. This is comparable to the mean of 2.22 chicks fledged per successful nest which I observed for area B on the Orange County study area, although Henny's data are probably biased upward by equating number of banded chicks with number of fledged young. In contrast to the "all-or-nothing" harvesting situation observed at Red-tailed Hawk nests, all of the nestlings were not consistently taken from those Red-shouldered Hawk nests plundered by man. Five of the ten nests robbed by man during the nestling period had all chicks taken from them (accounting for 11 young). At the remaining five nests, at least one nestling was left in the nest. Responses to the cards posted at nests disclosed one nest had one young removed and another nest had two taken (both nests had young left in them). The respondents said the birds were taken for falconry. At a third nest youths were observed taking one nestling (one was left in the nest) which they said was to be used for falconry. Evidence from spike scars indicated man was responsible for the disappearance of three chicks from two other nests.

Nest success for the total study area was 65.5%. Nest success of area A (55.5%) varied greatly from the area B success (81.8%).

Eggshell thickness of 31 Red-shouldered Hawk eggs from the Orange County study area averaged 13.9% thinner than pre-1947 data given by Anderson and Hickey (1972) for the western United States (table 3). When treated on a clutch basis, eggs from nests which contained unhatched eggs showed a significant ($P < 0.001$) difference in eggshell thickness compared with eggs in nests in which all eggs hatched (table 4). Despite the magnitude of thinning, no broken eggs were found during the study. Eggshell thinning, a condition associated with pesticide contamination (Ratcliffe 1967, Hickey and Anderson 1968, Porter and Wiemeyer 1969, Peakall 1970), has been observed in other Red-shouldered Hawk populations, including a 3 to 13% decrease in southern California eggshell weights since 1955 (Anderson and Hickey 1972). In Ontario, Red-shouldered Hawk nests have been found with broken eggshells (Goodwin and Rooche 1971), possibly as a result of pesticide-related eggshell thinning. Henny et al. (1973) checked residues of organochloride insecticides and polychlorinated biphenyls in three Red-shouldered Hawk eggs from Maryland and concluded that the level of dieldrin (0.16–0.35 ppm) in combination with the p,p'-DDE (0.79–2.40 ppm) might be sufficient to produce the 9% decrease in eggshell thickness which was observed but was not high enough to have a detrimental effect on the reproductive performance of the population. However, shell thinning of the magnitude which I observed during 1973 (–13.9%) deserves further investigation into its source and its effect on the population.

CONCLUSIONS

In the areas where young are not taken from nests by man (area B), Red-tailed Hawks appeared to produce sufficient young in 1973 to maintain the population on the study area. In fact, Red-tailed Hawk productivity in unharvested areas (2.06 fledged per nesting pair) was quite high relative to that reported from other investigations (0.9 fledged per adult pair—Craighead and Craighead 1956, 1.1 fledged per adult pair—Gates 1972, 1.4 fledged per breeding pair—Orians and Kuhlman 1956).

Although populations have declined significantly in many parts of the Red-shouldered Hawk's range (Peterson 1969, Wallace 1969, Gauthreaux 1971, Henny 1972), recent reports indicate that the California populations are maintaining themselves (Brown 1971, S. Wilbur 1973). This is interesting in light of the thin eggshells which I observed in 1973. The presence of thin eggshells in the Orange County populations is disturbing and indicates that reproductive problems may be forthcoming. Close monitoring of southern California Red-shouldered Hawk productivity and pesticide loads is needed. Clutch sizes for the Red-shouldered (and Red-tailed) Hawk in 1973 varied significantly from earlier clutch-size data (most prior to 1930) for southern California. It is not known whether this is a result of sampling error or whether there has been a real decline in number of eggs laid per nest. Here again, long-term observations are needed. In 1973, Red-shouldered Hawk productivity on Orange County areas where the young were not taken by man (1.82 fledged per nesting attempt) was comparable to that observed by Craighead and Craighead (1956) in Michigan (1.8 fledged per adult pair) and higher than that reported by Henny et al. (1973) for Maryland between 1960–71 (0.50–3.33 fledged per breeding pair; mean, 1.58). In the unharvested areas it appears that in 1973 the study area Red-shouldered Hawk population produced sufficient young to maintain itself although this cannot be used as a general estimate of the species' nesting performance for southern California. Raptor populations are subject to wide fluctuations from year to year and no overall conclusion can be drawn from one year's data for either species studied.

Although the effect of interference by man on these raptor populations requires more than a one-year investigation, my study shows the intensity of this form of predation. The percentage of unsuccessful nests in area A during incubation was five times as great as that in area B for the Red-tailed Hawk and nearly two times greater for the Red-shouldered Hawk. For both species the difference was even greater during the nestling period: success on area B was nearly 15 times as great for the Red-tailed and 3 times as great for the Red-shouldered Hawk when compared with area A.

SUMMARY

Nesting and reproductive performance of the Red-tailed and Red-shouldered Hawks were investigated in Orange County, California, during 1973. The study area was divided into two sections to study man's influence on raptor breeding success: area A was within one-quarter mile of a public road, while area B included only that region greater than one-quarter mile from a public road. Reproductive success on area A was much lower than that on area B primarily as a result of harvesting by man. Red-tailed Hawks produced 0.95 young per nesting attempt on area A and 2.06 per nest attempt on area B. Red-tailed Hawk nest success in area B was high (93.9% of the nests fledged young). Red-shouldered Hawk productivity in area B (1.82 chicks fledged per nesting attempt) was comparable to that observed by Craighead and Craighead (1956) in Michigan, although area A fledging success was considerably lower (1.06 fledged per nesting attempt). Red-shouldered Hawk nest success in area B was 81.8% and 55.5% in area A. Thirty-one eggshells of the Red-shouldered Hawks on the study area averaged 13.9% thinner than pre-1947 data for southern California eggshells. These measurements indicate a need for closely monitoring the nesting performance of the southern California Red-shouldered Hawk population. No first-year Red-tailed Hawks were observed breeding but 10.3% of the breeding Red-shouldered Hawk pairs had females in first-year plumage. Analysis of egg-collection data (majority of clutches collected prior to 1930) showed a significant difference between the means of these clutch sizes and those observed in 1973 for both the Red-tailed and the Red-shouldered Hawks.

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