# DECLINING RING-NECKED PHEASANTS IN THE KLAMATH BASIN, CALIFORNIA: II. SURVIVAL, PRODUCTIVITY, AND COVER

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ABSTRACT—Cover condition and its influence on nesting success, survival, and body condition of ring-necked pheasants (*Phasianus colchicus*) were evaluated at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR). Inadequate nesting cover was responsible for extremely low nest success early in the nesting season at TLNWR. Later in the season at TLNWR, spring-planted crops provided cover to conceal nesting and re-nesting hens; however, only 0.07 young were produced (to 1 August) per hen during the study. The extremely low reproductive rates were well below those required to maintain a stable population. At TLNWR, most adult mortality during spring and early summer (before crops provided adequate cover) apparently resulted from predation by golden eagles (*Aquila chrysaetos*). This mortality occurred weeks before insecticide applications. Hard winters (cold temperatures and heavy snowfall) periodically reduce the pheasant population in the Klamath Basin and again greatly reduced numbers during the last year of this study. Unfortunately, pheasant populations declined under the conditions found during this study and were unable to recover from the hard winter of 1992 to 1993. Mean body mass and tarsal length of adult hen pheasants at TLNWR, which is intensively farmed, were less than those for hens at LKNWR, which is not intensively farmed. Results of our study suggest that TLNWR hens may have been nutritionally stressed, and that the amount and distribution of vegetative cover needs to be improved at TLNWR. Habitat management of edge cover along agricultural crops should feature perennial grasses and legumes with small tracts of land interspersed throughout the agricultural fields to provide alternative cover for wildlife in general including pheasants.

Key words: ring-necked pheasant, *Phasianus colchicus,* body condition, California, cover, nesting success, predation, survival, radio telemetry

The exotic ring-necked pheasant (*Phasianus colchicus*), 1st successfully introduced into the United States in 1881 (Gabrielson and Jewett 1940; Lauckhart and McKean 1956; Laycock 1966; Weigand and Janson 1976), thrived for many years in California and other portions of

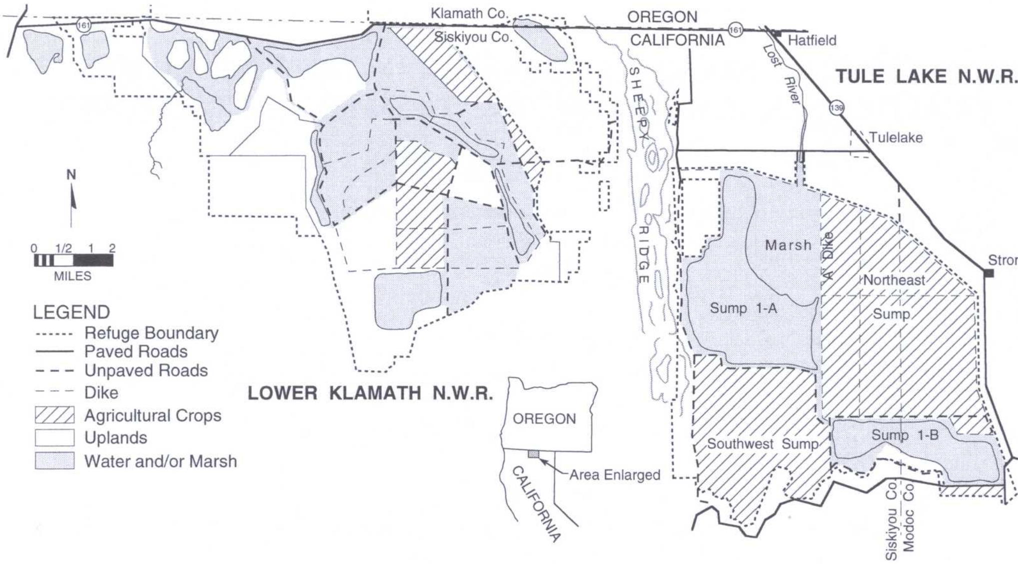


FIGURE 1. Map of Lower Klamath and Tule Lake National Wildlife Refuges.

the western United States. However, most pheasant populations have declined markedly in recent decades (Farris and others 1977; Jarvis and Simpson 1978; Warner 1981; Warner and others 1984). The population in California and Oregon's Klamath Basin is no exception (Zezulak 1990). Zezulak (1990) reported that the pheasant harvest at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR) declined from 7707 in 1974 to <1000 in 1987 based on check station counts. Gradual changes in agricultural land-use practices have been recognized as the primary reason for these declines (Labisky 1976; Farris and others 1977). Small, diversified farms have been incorporated into larger farms, which utilize larger tracts of land for monocultural crops, eliminating fence and/or hedge row edge habitat between smaller fields. Herbicides used to control economically important weeds in crops remove much of the cover associated with field edges, ditch banks, and disturbed areas. Springtime burning to remove residual cover also reduces available pheasant nesting and brood cover. Moreover, shorter field stubble and field tillage in the fall instead of the following spring remove important winter cover, thus reducing seasonal habitat. Last, insecticide use has been suggested as an important factor in declining pheasant numbers (Messick and others 1974).

We used radio telemetry to study a population of ring-necked pheasants associated with intensively farmed agricultural lands at TLNWR from the spring of 1991 through the spring of 1993 and compared those findings with a nearby population at LKNWR, which was not intensively farmed. Our work was initiated at the request of the U.S. Fish and Wildlife Service because of concerns about possible effects on wildlife populations of organophosphorus (OP) insecticides used at TLNWR. The ring-necked pheasant was chosen for this study because of its close association with agricultural lands and the availability of proven techniques for telemetry studies with these birds. However, it became apparent in 1991 that OP insecticides had a limited effect on pheasant numbers (Grove 1995; Grove and others 1998); thus, we investigated other factors in 1992. We modified the design of this comparative study at the 2 refuges to 1) estimate hen and brood survival, 2) evaluate hen body condition (body weight and tarsal length), and 3) determine placement and success of nest sites in relation to available cover.

## Study Areas

TLNWR is located in northern California's Siskiyou and Modoc Counties at 1220 m elevation along the California-Oregon border, 42 km SE of Klamath Falls, Oregon (Fig. 1). Much of the 15,830-ha refuge was once a large lake that was drained nearly 100 years ago. TLNWR includes Tule Lake, which acts as a sump for irrigation water from the Klamath Reclamation Project and covers 5478 ha of the refuge. Tule Lake is actually 2 large bodies of water (sumps 1-A and 1-B) connected by a narrow channel. An extensive marsh of bulrush (*Scirpus acutus*) and cattail (*Typha latifolia*) exists in the north ⅓ of sump 1-A (Fig. 1). A total of 6910 ha (44%) is intensively farmed at TLNWR, with ⅓ of the land planted in row crops: onions (*Allium cepa*), potatoes (*Solanum tuberosum*), and sugar beets (*Beta vulgaris*). The remaining land is planted in cereal grains: barley (*Hordeum vulgare*), oats (*Avena sativa*), and wheat (*Triticum aestivum*) as well as alfalfa (*Medicago sativa*). Pheasant cover in winter and spring was limited to that on dikes and drains (Fig. 2), where five-hook bassia (*Bassia hyssopifolia*), kochia (*Kochia scoparia*), and nettle (*Urtica dioca*) dominated the vegetation.

LKNWR, located west of TLNWR, was used as a reference area for this study. The 21,691-ha refuge is separated from TLNWR by Sheepy Ridge, which rises 244 m above the valley floor, preventing significant pheasant movement between the 2 study areas. LKNWR uses water pumped from Tule Lake through Sheepy Ridge to provide waterfowl habitat. Units within the refuge are periodically flooded and drained on an alternating basis to control disease and quackgrass (*Agropyron repens*). The man-made ponds, fallow field-temporary marsh, and uplands are interspersed with 1200 to 2000 ha (5 to 9% of land area) of crop lands planted annually to barley, oats, and wheat. The extensive flooded and marshy areas at LKNWR restrict pheasant cover to levees, canal banks, drains, and fallow field-temporary marsh (Fig. 3). Vegetation was similar to that at TLNWR except that much of the uplands were planted to crested wheatgrass (*A. cristatum*). Insecticides were used on crop lands at TLNWR but not at LKNWR.

## METHODS

### *Capture, Radio Attachment, and Monitoring*

We trapped and radio-tagged pheasant hens to evaluate nest site placement and cover structure, nest success, and hen and brood survival. Hen pheasants were trapped at 5 sites at each refuge from 1 April to 15 May of 1991 and 1992 with walk-in funnel traps (Bub 1991). Captured hens were weighed prior to radio-tagging during both years. In 1991, we noted smaller hens, based on body weight, at TLNWR compared to hens at LKNWR, so we also measured tarsus length in 1992 to determine if the skeletal system was also smaller. All hens were considered adults by April because pheasant young reach maximum skeletal growth and body weight 6 mo after hatching (Kirkpatrick 1944) and lay eggs as yearlings (Labisky and Jackson 1969).

Hens were fitted with necklace radio transmitters (Advanced Telemetry Systems, Isanti, MN) that weighed approximately 16 g (1.6% of body weight) (Marcström and others 1989; Riley and Fistler 1992). Transmitters were equipped with mortality switches that doubled the normal pulse rate when hens remained motionless for more than 5 hr. The mortality switch also indicated hen activity (mercury-switch modulated) by adding pulses to the normal pulse rate based on how much the radio was moved per unit time (Kenward 1987). Mercury switch modulation enabled us to detect hen activities such as foraging, dusting, and the initiation of incubation.

Hens were located via a vehicle-mounted, 4-element, dual-beam antenna system or a 3-element, hand-held Yagi antenna. We used the null-peak system to take bearings on each bird from at least 2 receiver sites. Locations were determined using the program XYLOG4 (Dodge and Steiner 1986), with directional bearing accuracy determined using techniques described in White and Garrott (1990). We checked hens daily during the field season to identify status and activity (alive, dead, nesting). Hen locations were triangulated after 15 June when field crop cover became available. In 1991, hen locations were triangulated daily from 15 June to 30 August, while in 1992, hens were located on alternating days because more radio-tagged hens were monitored. Hen survival was monitored monthly after August when field activities had ceased for the year. In 1992, hens overwintering with radios (those not re-trapped and fitted with new radios) were monitored until the radios stopped transmitting, became detached, the hens died, or the hens were collected by shotgun to determine brain cholin-

esterase activity during the insecticide portion of the study (Grove and others 1998).

*Cover Evaluation*

We measured height of available residual cover (dead vegetation) and of growing plants in areas with pheasant activity at TLNWR and LKNWR in 1992. Cover types evaluated at the 2 refuges were dike, fallow field-temporary marsh, grain, onion, potato, and sugar beet. A vegetation board was constructed for measuring cover height using a modification of techniques described in Thompson (1975) and Nudds (1977). The white board was 1.0-m wide by 1.5-m tall, overlaid with a decimeter grid. Cover height was noted in each of the 10-dm columns across the sample board from a distance of 10 m. A mean of all columns was calculated for each site sampled. Five dikes were randomly selected at each refuge with 10 sampling stations randomly located along a 3-km distance of each dike. Random selections (dikes, stations, points) were made using a random number program from Statistical Analysis System (SAS; SAS Institute Inc. 1985). Seven fallow fields-temporary marshes were sampled at LKNWR, with a sampling station randomly located along the length of each field selected. Cover height was measured at 5 randomly selected points along a 100-m transect from each station. Fallow field-temporary marsh cover type was absent at TLNWR. Cover was measured at 2-wk intervals from 12 May to 17 July, with each refuge sampled on alternate weeks. Residual cover height and growing plant height were measured on the 1st sampling date at marked stations on dikes and fallow fields-temporary marshes, with repeated measurements of growing plant height on subsequent sampling dates. Crop fields were randomly selected for repeated measure of cover height from established fields at both refuges. Cover height was measured along a transect at 5 locations, starting at 20 m in from the field edge, at 20-m intervals towards the field center. Cover height was measured in 7 grain fields at LKNWR and 14 grain fields (7 early plantings and 7 late plantings), 2 onion fields, 5 potato fields, and 2 sugar beet fields at TLNWR for each sampling interval. Crop fields had homogenous growth; therefore, new transects in crop fields were selected for each sampling interval to minimize crop damage.

*Nest Distribution and Success*

Hens remain motionless during incubation to avoid attracting predators (Breitenbach and others 1965; Hill and Robertson 1988). Radio-tagged pheasant hens were recorded as initiating incubation when they were plotted at the same location for 2 to 3 consecutive days or when no movement occurred for 10 min (no radio modulation). A hand-held antenna was used to locate pheasant nests; a flag 10 m away was used to mark each nest. We avoided flushing hens from their nests to minimize disturbance, possible nest abandonment, or predation. Hatching was determined by hen activity obtained from telemetry, while clutch initiation dates were extrapolated using a 23-day incubation period and an additional 1.3 days per egg laid (Bent 1932; Labisky and Opsahl 1958; Weigand and Janson 1976). We identified a successfully hatched nest by the presence of detached shell membranes (Klett and others 1986). A nest was considered successful if ≥1 egg hatched. We estimated nest success as the percentage of nests hatching where incubation was attempted. Nests destroyed by predators were identified using field experience and published techniques (Rearden 1951; Murie 1954; Einarsen 1956; Halfpenny 1986; Stokes and Stokes 1986; Sargeant and others 1998).

Residual cover of each nest was recorded after nest fate was determined. Height of residual vegetation cover was determined at 4 locations radiating out from a nest at 90° intervals by viewing a pole placed at the center of a nest from 4 m away (Robel and others 1970). The 4 measurements were averaged to determine mean cover height for each nest. Cover height at nests located in agricultural crops was determined near the nest because crop height throughout the field was homogeneous.

Hens with broods were followed during the telemetry study to determine brood survival.

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FIGURE 2. Springtime cover on dikes and drains at Tule Lake National Wildlife Refuge, 1991 (top) and 1992 (middle, bottom).

Hens with broods that survived to August were located using a hand-held Yagi antenna. The broods were flushed ≤3 times to get an accurate count of young. A brood was considered successful if ≥1 young survived to 1 August. Annual estimated pheasant recruitment was calculated for each refuge by dividing the number of pheasant young surviving by the number of hens initially radio-tagged.

Supplemental nest searches were conducted at TLNWR along "A" dike, which had the majority of available nesting cover, and other dikes, drains, road sides, and areas of available cover when radio-tagged hens began incubation. Nest searches were conducted once per week between 0900 to 1200. The incubation stage of active nests was determined by candling or egg-flotation techniques (Westerkov 1950; Weller 1956; Labisky and Opsahl 1958; Carroll 1988). These data provided additional information on nesting and predation of pheasants at TLNWR.

*Adult Mortality*

Hen pheasants with radio transmitters that switched over to the mortality pulse rate were immediately located to determine their fate. We noted whether each hen was alive or dead and the circumstances (nesting, roadkill, predation, type of predator, carcass eaten) (Murie 1954; Hawthorne 1980; Halfpenny 1986; Stokes and Stokes 1986). Body remains were necropsied and radios were reused. Tarsus lengths of radioed hens collected as mortalities during the 1991 field season were measured. Hens collected by shotgun during the insecticide portion of the study, in the summer months of 1991 and 1992, were also weighed and measured (tarsus lengths).

Supplemental adult mortality data were collected from roads and dikes at 2-day intervals in the northeast sump of TLNWR where bare fields and sparsely covered field edges made carcass searches and predator identification possible. Although the mortality searches do not represent a random sample, the large number of dead pheasants found warranted their documentation. Mortality information at LKNWR for adult pheasants was restricted to radio-tagged birds because residual cover and plant growth made carcass searches impossible.

*Population Model*

Survival rates of 1st-yr hens were not available for either area or year. We assumed that the survival rate for 1st-yr hens equaled the survival rate of adults estimated by the model developed by Kaplan and Meier (1958). This is likely an overestimate of 1st-yr survival because 1st-yr hens generally survive at a rate lower than ≥2nd-yr hens (Petersen and others 1988). Based on annual survival rates in 1991, we calculated the average productivity needed for populations at TLNWR and LKNWR to remain stable using the equation of Henny and others (1970).

*Statistical Methods*

Data were analyzed using SAS. Data were examined for normality using box plots, stem and leaf displays, the Shapiro-Wilk test (Shapiro and Wilk 1965), and normal probability plots. The data were also tested for equal variances using the F-test.

A 2-way ANOVA was used to test spring hen body mass and tarsal length for differences between refuges and years (Tukey's Studentized Range Test, overall $\alpha = 0.05$). A Kruskal-Wallis test was used to test summer hen body mass between refuges and years.

A 1-way ANOVA was used to test for differences in residual cover height for dike and fallow field-temporary marsh data collected in 1992. A 1-way ANOVA was used to test for differences in the growth of vegetation by comparing regression slopes from sampling stations on dikes and fallow fields-temporary marshes and crop sampling sites.

The Wilcoxon rank-sum test was used to test for differences among unequal sample sizes for clutch sizes, clutch completion dates, and days to detection using telemetry. Mayfield estimates for nest success were made using radio-tagged hens at TLNWR and LKNWR (Mayfield 1961, 1975; Bart and Robson 1982). Compari-

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FIGURE 3. Springtime cover on dikes and drains at Lower Klamath National Wildlife Refuge, 1991 (middle) and 1992 (top, bottom).

TABLE 1. Spring body mass (g) and tarsal length (mm) of adult ring-necked pheasant hens trapped or collected at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR), 1991–92.

| Category | | TLNWR | | LKNWR | | Results of ANOVA tests ($P$) | | |
|---|---|---|---|---|---|---|---|---|
| | | 1991 | 1992 | 1991 | 1992 | Year | Refuge | Interaction |
| Body mass | $\bar{x}$ | 925.6 | 963.1 | 993.0 | 1055.0 | 0.0067 | 0.0001 | 0.4994 |
| | SD | 104.9 | 80.2 | 102.3 | 82.9 | | | |
| | $n$ | 36 | 39 | 15 | 29 | | | |
| Tarsal length | $\bar{x}$ | 63.6 | 64.9 | 66.2 | 67.0 | 0.0556 | 0.0001 | 0.6579 |
| | SD | 2.7 | 2.5 | 2.0 | 2.2 | | | |
| | $n$ | 20 | 53 | 9 | 34 | | | |

sons of Mayfield estimates were made using a modified Chi-squared test procedure described by Sauer and Williams (1989).

Survival functions of radio-tagged pheasant hens were estimated using the product limit estimator (Kaplan and Meier 1958) as modified by Pollock and others (1989) to accommodate the addition of new animals throughout the study. A Chi-square test was used to compare survival estimates.

## Results

### *Body Weight and Tarsus Length of Hens*

Forty-nine hen pheasants were trapped and tagged with radio necklaces in 1991 (34 at TLNWR and 15 at LKNWR), and 64 new hens were trapped and radio-tagged in 1992 (36 at TLNWR and 28 at LKNWR). At the beginning of the 1992 field season, 18 radio-tagged hens (11 at TLNWR and 7 at LKNWR) had successfully overwintered with functioning radios. Two of these hens at TLNWR and 1 at LKNWR were retrapped and their old radios replaced. In 1992, 82 hens were radio-tagged; 47 were at TLNWR and 35 were at LKNWR.

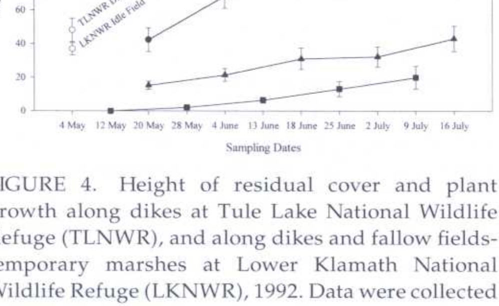


FIGURE 4. Height of residual cover and plant growth along dikes at Tule Lake National Wildlife Refuge (TLNWR), and along dikes and fallow fields-temporary marshes at Lower Klamath National Wildlife Refuge (LKNWR), 1992. Data were collected at biweekly intervals.

All hen pheasants trapped and radio tagged in the spring of 1991 and 1992 appeared healthy, but hens at TLNWR weighed less than hens at LKNWR ($P = 0.0001$) (Table 1). A 2-way ANOVA showed a year effect and a refuge effect, but no refuge × year interaction. On average, hens at TLNWR were 6.8% and 8.7% lighter than those at LKNWR in 1991 and 1992, respectively. Pheasant hens weighed significantly more ($P < 0.003$, $n = 119$) in the spring of 1992 ($\bar{x} \pm$ SD $= 1002.3 \pm 93.2$ g) than in 1991 ($\bar{x} \pm$ SD $= 945.4 \pm 107.7$ g). Body masses of hens collected in the summer during the insecticide portion of the study did not differ significantly between years or refuges (Grove 1995).

Tarsal length of hens trapped in 1992 and hens collected in 1991 and 1992 paralleled the body mass data. Tarsal length was related to refuge and year, with no interaction (Table 1). TLNWR hens had shorter tarsi than LKNWR hens in both 1991 and 1992.

### *Cover*

Mean residual cover height along dikes and drains at TLNWR (48.2 cm) and in fallow fields-temporary marshes at LKNWR (36.9 cm) was shorter ($P = 0.001$) than cover on dikes and drains at LKNWR (119.7 cm) in 1992 (Fig. 4). The mean growth slopes for vegetation along dikes and drains at TLNWR of 0.37 cm/day and fallow fields-temporary marshes at LKNWR of 0.47 cm/day were less than the slope of 1.49 cm/day for dikes and drains at LKNWR (Fig. 4; $P = 0.001$).

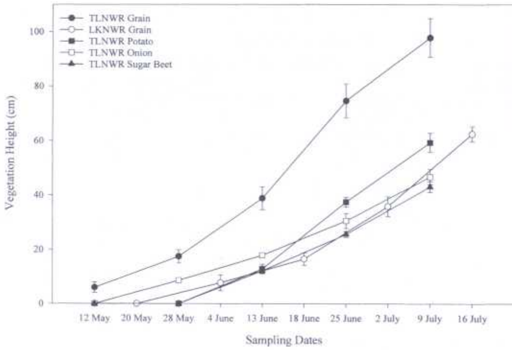


FIGURE 5. Vegetation height of grain and row crops at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR), 1992. Data were collected at biweekly intervals.

Grain comprised 69% of the total crops grown at TLNWR, which was about 47% of the total land available for pheasant use at TLNWR. However, field cover by grain at TLNWR in 1991 and 1992 did not reach 30 cm (the height of adult pheasants) until early June (Fig. 5). Grain fields at LKNWR, which represented about 23% of the land area available to pheasants, did not exceed 30 cm until late June. The growth-rate slope of 1.62 cm/day ($n = 70$) for grain crops at TLNWR was greater ($P = 0.01$) than the slope of 1.10 cm/day ($n = 35$) at LKNWR (Fig. 5). The growth-rate slopes for onions, potatoes, and sugar beets were 0.8 cm/day ($n = 10$), 1.5 cm/day ($n = 25$), and 1.0 cm/day ($n = 10$), respectively, but these crops were not represented at LKNWR (Fig. 5). However, the combined growth-rate slope of 1.2 cm/day for row crops at TLNWR was less than for grain crops at TLNWR ($P < 0.01$), but not significantly different from grain crops at LKNWR.

*Nesting*

During 1991 and 1992, radio-tagged hen pheasants began nesting in late May and mid-April, respectively, at both TLNWR and LKNWR. Eleven of 24 hens (46%) at TLNWR and 10 of 12 (83%) hens at LKNWR initiated incubation in 1991, with nearly identical percentages in 1992 (22 of 48 hens [46%] at TLNWR and 29 of 34 hens [85%] at LKNWR). Nests depredated very early in incubation may have been missed.

During 1991 and 1992, 3 of 11 hens and 16 of 22 hens, respectively, at TLNWR nested in residual cover. The remaining nests at TLNWR were mostly in spring-planted grain fields and were initiated later in the nesting season (≥15 June for both years) when that cover became available. All renests after 15 June at TLNWR (2 in 1991, 4 in 1992) were located in farm crops. All nests and renests at LKNWR were placed in residual cover. The nesting season (1st nest initiated to last nest hatched) at TLNWR was 38 and 11 days longer than at LKNWR in 1991 and 1992, respectively.

Mean (± SD) height of residual nest cover at TLNWR (27.7 ± 28.5 cm, $n = 3$) in 1991 was not significantly shorter than at LKNWR (60.5 ± 20.6 cm, $n = 11$), but sample sizes were small. In 1992, mean height (± SD) of residual cover at nests was shorter ($P = 0.004$) at TLNWR (47.6 ± 18.5 cm, $n = 14$) than at LKNWR (72.1 ± 30.8 cm, $n = 38$). Mean (± SD) cover height for nests in grain fields, including renests, at TLNWR was shorter ($P = 0.002$) in 1991 (62.0 ± 14.8 cm, $n = 9$) than in 1992 (89.4 ± 13.8 cm, $n = 8$). One 1991 TLNWR renest attempt was located in an irrigated onion field with vegetation 55 cm high, while 1 initial nest attempt and 1 renest attempt in 1992 were in potato fields with a mean (± SD) cover height of 59.5 ± 2.1 cm. No nests were detected in grain fields at LKNWR in either year.

Nests in 1991 with clutch completion dates from 31 May to 14 July had a smaller mean (± SD) clutch size ($P = 0.047$) at TLNWR (7.0 ± 1.6 eggs/clutch, $n = 7$) than LKNWR (9.0 ± 1.8 eggs/clutch, $n = 9$), although in 1992 (10 April to 15 June), the mean (± SD) clutch size at TLNWR (8.6 ± 2.4 eggs/clutch, $n = 14$) was not significantly different than the mean (± SD) clutch size at LKNWR (10.0 ± 2.6 eggs/clutch, $n = 26$).

Initiation of incubation was detected sooner at LKNWR than at TLNWR in both 1991 ($\bar{x}$ ± SD = 1.9 ± 5.2 days, $n = 10$ vs 5.1 ± 4.1 days, $n = 9$; $P = 0.028$) and 1992 ($\bar{x}$ ± SD = 2.3 ± 4.0 days, $n = 27$ vs 8.8 ± 6.6 days, $n = 8$; $P = 0.021$). Telemetry indicated that hens at TLNWR were at their nests because no lateral movement was detected, but they did not remain motionless during the 1st several days of incubation.

During 1991 and 1992, radio-tagged hens hatched eggs in 33% and 46% of nests at TLNWR and LKNWR, respectively (Table 2). Avian and mammalian predation were major

TABLE 2. Nest fate of hens with and without radios at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR), 1991–92. NA = not applicable.

| Parameter | Radio-tagged | | Not radio-tagged[a] |
|---|---|---|---|
| | TLNWR | LKNWR | TLNWR |
| Initial nests | | | |
| Number of nests | 33 | 39 | 113[b] |
| Number hatched | 11 (33%) | 18 (46%) | 5 (4%) |
| Number abandoned | 5 (15%) | 3 (8%) | 2 (2%) |
| Number destroyed | | | |
| Mammalian | 9 (27%) | 12 (31%) | 56 (50%) |
| Avian | 7 (21%) | 2 (5%) | 22 (19%) |
| Farm equipment | 0 | 1 (3%) | 21 (19%) |
| Fire | 0 | 1 (3%) | 0 |
| Flood | 0 | 2 (5%) | 0 |
| Researcher | 1 (3%) | 0 | 0 |
| Unknown | 0 | 0 | 7 (6%) |
| Renests | | | |
| Number of nests | 6 | 10 | NA |
| Number hatched | 4 (67%) | 8 (80%) | NA |
| Number abandoned | 1 (17%) | 0 | NA |
| Number destroyed | | | |
| Mammalian | 0 | 1 (10%) | NA |
| Avian | 1 (17%) | 0 | NA |
| Researcher | 0 | 1 (10%) | NA |

[a] Data were not collected for pheasants without radio tags at LKNWR.
[b] When 1st located, 72 nests had already failed.

causes of nest failure. Nests of 113 non-radio-tagged hens were located along dikes at TLNWR in 1991 and 1992. Only 4% of these nests hatched (most along "A" dike) (Table 2). In this supplemental data set, depredation occurred prior to nest discovery at 72 of 113 nests. Avian and mammalian predators destroyed most nests along the dikes. One of the only other locations at TLNWR where hens could nest early was a small hay field along "A" Dike. Hens without radios were killed at 17 of 21 nests destroyed by hay swathers in 1991 and 1992. Renests of radio-tagged hens at both refuges were more successful than initial nesting attempts in 1991 and 1992.

Mayfield estimates for nest success showed no significant differences in overall daily survival rates in 1991 between nests of radio-tagged hens at TLNWR and nests at LKNWR (Table 3). The overall daily survival rate for nests of radio-tagged hens was significantly higher at LKNWR ($P = 0.017$) in 1992. Daily survival rates for years combined were also higher at LKNWR ($P = 0.049$). For refuges combined, no significant differences were noted for daily survival rates between 1991 and 1992. Based on observations of radio-tagged hens during 1991 and 1992, 3 of 15 broods survived to 1 August at TLNWR, while 9 of 26 broods survived to 1 August at LKNWR. Radio-tagged hens produced a mean 0.07 young at TLNWR and 0.44 at LKNWR.

*Adult Survival and Productivity Requirements*

Documented mortality of radio-tagged pheasant hens at TLNWR and LKNWR between 1 April 1991 and 31 March 1992 was 65% and 47%, respectively (Table 4). Deaths of all hens (except 1 killed at each study area in November) occurred between 1 April and 30 September 1991, with all other radio-tagged hens accounted for through March 1992.

Documented mortality of radio-tagged hens between 1 April 1992 and 31 March 1993 was 49% for TLNWR and 51% for LKNWR, although 19 hens (13 at TLNWR and 6 at LKNWR) were not relocated following severe cold and snow during the winter of 1992 to 1993. Eleven TLNWR hens and 10 LKNWR hens died between 1 April and 30 September 1992; 12 and 8 documented deaths occurred at each refuge, respectively, between 1 October 1992 and 30 March 1993. Predation was the major cause of hen loss, resulting in 95% and 100%

TABLE 3. Estimated nest success of radio-tagged ring-necked pheasant hens at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR), 1991–92, using Mayfield's (1961) technique as modified by Bart and Robson (1982).

| Category | Number of nests | Daily survival rate | SE | Nest success (%) |
|---|---|---|---|---|
| TLNWR | | | | |
| 1991 | 13 | 0.962 | 0.037 | 25.3 |
| 1992 | 24 | 0.929 | 0.044 | 7.7 |
| LKNWR | | | | |
| 1991 | 11 | 0.946 | 0.042 | 14.5 |
| 1992 | 37 | 0.976 | 0.027 | 42.9 |
| Years combined | | | | |
| TLNWR | 37 | 0.944 | 0.028 | 13.4 |
| LKNWR | 48 | 0.970 | 0.023 | 34.6 |
| Refuges combined | | | | |
| 1991 | 24 | 0.955 | 0.028 | 19.7 |
| 1992 | 61 | 0.964 | 0.023 | 27.4 |

of the mortality at TLNWR and LKNWR in 1991, respectively, and 74% at TLNWR and 61% at LKNWR in 1992. Golden eagles (*Aquila chrysaetos*) were the major predator, killing 38% and 33% of the radio-tagged hen population at TLNWR and LKNWR, respectively, in 1991 and 26% at TLNWR and 20% at LKNWR in 1992. One hen at TLNWR in 1991 and 1 hen at LKNWR in 1992 died of avian tuberculosis. Severe weather conditions (deep snow and cold temperature) during the winter of 1992 to 1993 resulted in the confirmed deaths of 10 radio-tagged hens, 5 each at TLNWR and LKNWR, and possibly 19 additional radioed hens that could not be found after the severe weather (Table 4).

Remains of 153 additional adult pheasants without radios were found during searches along dikes and roads adjacent to bare fields and sparsely covered field edges at TLNWR in 1991 and 1992 (Table 5). Hens accounted for 71% and 68% of the carcasses recorded in 1991 and 1992, respectively. The major mortality factor was avian and mammalian predation, which accounted for 82% and 47% of the documented hen deaths for 1991 and 1992, respec-

TABLE 4. Apparent cause of death of radio-tagged ring-necked pheasant hens at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR), 1991–92.

| | TLNWR | | LKNWR | |
|---|---|---|---|---|
| | 1991 | 1992 | 1991 | 1992 |
| Number of radio-tagged hens | 34 | 47 | 15 | 35 |
| Cause of death | | | | |
| Golden eagle (*Aquila chrysaetos*) | 13 | 12 | 5 | 7 |
| Northern harrier (*Circus cyaneus*) | 1 | 0 | 0 | 2 |
| Unknown raptor | 2 | 1 | 0 | 1 |
| Coyote (*Canis latrans*) | 2 | 1 | 0 | 0 |
| Mink (*Mustela vison*) | 2 | 0 | 0 | 1 |
| Raccoon (*Procyon lotor*) | 1 | 3 | 0 | 0 |
| Unknown mammal | 0 | 0 | 2 | 0 |
| Farm equipment | 0 | 0 | 0 | 1 |
| Roadkill | 0 | 1 | 0 | 0 |
| Avian tuberculosis | 1 | 0 | 0 | 1 |
| Winter kill | 0 | 5[a] | 0 | 5[a] |
| Total deaths | 22 | 23 | 7 | 18 |

[a] Winter kill probably accounted for another 13 hens at TLNWR and 6 hens at LKNWR whose radio signals were lost during the harsh winter of 1992–93.

TABLE 5. Apparent cause of death of non-radio-tagged ring-necked pheasants found dead at Tule Lake National Wildlife Refuge, 1991–92.

| Cause of death | 1991 | | 1992 | |
|---|---|---|---|---|
| | Female | Male | Female | Male |
| Golden eagle (*Aquila chrysaetos*) | 69 | 35 | 7 | 8 |
| Great-horned owl (*Bubo virginanus*) | 1 | 0 | 0 | 0 |
| Red-tailed hawk (*Buteo jamaicensis*) | 1 | 1 | 0 | 0 |
| Unknown falcon | 0 | 1 | 0 | 0 |
| Raccoon (*Procyon lotor*) | 4 | 0 | 0 | 0 |
| Unknown mammal | 0 | 0 | 1 | 0 |
| Farm equipment | 10 | 0 | 7 | 0 |
| Roadkill | 6 | 0 | 2 | 0 |
| Total | 91 | 37 | 17 | 8 |
| | 128 total | | 25 total | |

tively, and 100% of the roosters for both 1991 and 1992. Golden eagles accounted for 76% and 95% of hen and rooster deaths in 1991, respectively, and 41% of the hen and 100% of the rooster deaths in 1992. Farming activity and roadkills accounted for 18% and 53% of those documented in 1991 and 1992, respectively.

Annual survival estimates of radio-tagged hen pheasants in 1991 (spring of 1991 to spring of 1992) were 27.5% at TLNWR and 53.3% at LKNWR (Fig. 6). Survival estimates during 1992 for hen pheasants at both TLNWR and LKNWR were 0%. Most adult mortality at TLNWR occurred between 1 April and 30 June of each year when little crop cover was available. No significant difference was found in the pattern or timing of adult mortality (as described in Pollock and others 1989) between TLNWR and LKNWR for the interval from 1 April to 30 June in either 1991 or 1992, but this was probably related to low sample sizes at LKNWR in 1991. A difference was found in patterns between 1991 and 1992 at TLNWR ($P = 0.01$). Survival patterns were also different ($P = 0.004$) between years with refuges combined.

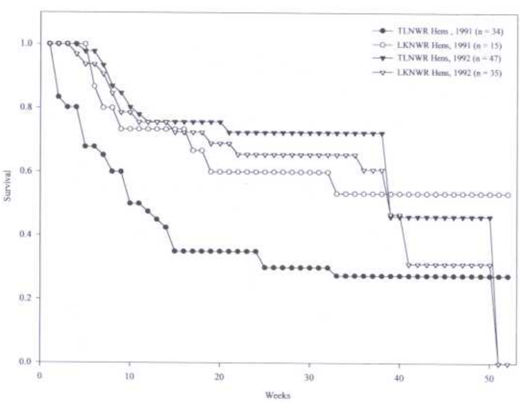


FIGURE 6. Survival estimates of radio-tagged adult ring-necked pheasant hens at Tule Lake National Wildlife Refuge (TLNWR) and Lower Klamath National Wildlife Refuge (LKNWR), 1991 and 1992, using the Kaplan-Meier survival function, modified for staggered animal entry. Hens were monitored from 1 April 1991–92 and 1992–93.

Based on the survival rates described above, we estimated an average productivity requirement of 5.3 and 1.8 young per hen, respectively, for TLNWR and LKNWR pheasant populations to remain stable in 1991. Similar calculations could not be made for TLNWR or LKNWR during 1992 because no radio-tagged hens survived to the spring of 1993.

## Discussion

We studied a long-term declining pheasant population that did not rebound after a recent severe winter. In attempting to understand why, we evaluated several factors that might be responsible. Pesticide applications during the summer were evaluated, and radio-tagged hens at TLNWR did not die as a direct result of insecticide intoxication during the summers of 1990 to 1992 (Grove 1995; Grove and others 1998). However, 68% of the adult pheasants collected during the insecticide phase of the study were exposed to organophosphorus insecticides and exhibited brain cholinesterase inhibition of 19 to 62%. Two young pheasants were killed by direct insecticide toxicity. No young were radio-tagged, so the extent of the direct toxicity of insecticide exposure on survival rates of young remains unknown. However, loss of insects killed by insecticides may have contributed to food shortages and indirectly influenced survival.

We then evaluated population parameters such as survival rates, production rates, and predation rates by comparing TLNWR with LKNWR with the published literature. Spring-to-fall survival of adult hen pheasants at both refuges in 1991 and 1992 was at or above the 30 to 35% considered typical of self-sustaining populations in which reproduction keeps pace with mortality (Petersen and others 1988). Reproduction, however, at both TLNWR and LKNWR did not keep pace with mortality. Most reproductive losses were due to mammalian predation, primarily by raccoons and skunks. With Mayfield nest success at TLNWR at 13.5% and brood survival at 20%, reproduction was clearly inadequate. The population model estimated an average productivity of 5.3 young per hen and 1.8 young per hen, respectively, would be needed to maintain a stable population based on annual adult survival at TLNWR and LKNWR. Actual productivity, based on marked hens, of 0.07 young per hen at TLNWR and 0.44 young per hen at LKNWR was far below the minimum required. Productivity at LKNWR, although better than TLNWR, also did not support a stable pheasant population.

The lack of residual cover at TLNWR during winter and spring restricted most pheasant activity during this study to the northern half of "A" dike, which is adjacent to a large bulrush marsh. Zezulak (1990) also found the majority of pheasants in the northern portion of the refuge in 1989 where marsh was the most frequently used cover type for TLNWR pheasants during winter and spring. The marsh provided roosting cover, thermal protection, and protection from predators (Zezulak 1990). Gatti and others (1989) found marsh cover an important winter and spring cover component for pheasants in Wisconsin, while Farris and others (1977) described cattail sloughs as important habitat during winter and spring months in Iowa. Pheasants at TLNWR, however, had to venture out into open, bare fields to forage (especially in spring), which made them vulnerable to predation (Snyder 1985). Even minimal cover was not available for pheasants away from "A" dike until after 1 June, when crop height provided cover to conceal pheasants from predators. The 1991 and 1992 growth of spring and summer vegetation along dikes and field edges at TLNWR did not provide cover for pheasant concealment.

Hen pheasants had a paucity of cover for early spring nesting at TLNWR. Later, spring-planted crops (mainly cereal grains) provided concealment for nesting hens. Avian and mammalian predation accounted for loss of most early nesting attempts situated in sparse cover. Nest success was also low at LKNWR in 1991 when most nests were on dikes of flooded impoundments. These nests were vulnerable to mammalian predators who use the dikes as travel lanes (Chesness and others 1968; Haensly and others 1987). Agricultural practices at TLNWR provide little edge cover for pheasant broods. Warner (1984) and Hill and Robertson (1988) report that hens with broods in large, homogenous monocultural crop settings tend to range farther to forage and suffer higher mortality when compared with broods in more diverse habitat settings. Monocultural crops usually have low numbers and few insect species (Warner 1979; Warner 1984; Warner and others 1984). Furthermore, pesticide (fungicides, herbicides, insecticides) applications during brood rearing decrease the insects available for pheasant chicks (Messick and others 1974; Warner 1984; Warner and others 1984; Hill 1985; Hill and Robertson 1988), which can also cause broods to move greater distances, thus increasing chances for separation from the brood, depredation, and hunger.

Finally, general condition of the pheasants, especially at TLNWR, and the potential effects on various population parameters requires discussion. Pre-nesting spring body mass of hens from Illinois, Michigan, and Nebraska ranged between 1020 to 1216 g (Wight 1945; Mohler 1959; Warner and Etter 1983), which was much higher than the 945 g mass of hen pheasants trapped in the spring at TLNWR. Hens collected in July and August of 1991 and 1992 at TLNWR and LKNWR were 20 to 25% lighter than hens weighed in the spring. Kabat and others (1956) and Breitenbach and others (1963) showed that hen pheasants reach their physical peak prior to egg laying and will lose approximately 20% of their body mass during egg laying, incubation, brooding, and molting (Labisky and Jackson 1969). The birds in our study underwent this standard loss from below-normal body mass prior to egg laying. Hens at TLNWR also had significantly shorter tarsi than those at LKNWR. Reduction in skeletal size (stunted growth) may have resulted from late nesting or repeat nesting, which produce broods that have inadequate time for normal growth before winter, or from the lack of appropriate food later in the nesting cycle (insects and young forbes during the early stages of growth). Furthermore, only 46% of the radio-tagged hens at TLNWR nested during this study as opposed to 83 to 85% at LKNWR. Hens in poor body condition nest later (Barrett and Bailey 1972) and do not nest as readily (Persson and Göransson 1999). Also, only 10 to 24% of radio-tagged hens renested after losing their 1st clutch at each refuge in 1991 and 1992. Generally, >60% of hen pheasants renest after losing their 1st clutch (Dumke and Pils 1979; Hill and Robertson 1988). In addition, smaller clutch sizes were reported in 1991 and 1992 (7.0 and 8.6 eggs) at TLNWR than at LKNWR (9.0 and 10.0 eggs). Mean clutch size reported in the literature ranges from 10.3 to 11.8 (Mohler 1959; Dumke and Pils 1979; Hill and Robertson 1988), with clutch size decreasing as the season progressed. Kabat and others (1950) reported that much of the decline in body reserves of hens is due to egg laying. Once incubation begins, pheasant hens sit quietly, moving very little to avoid attracting attention (Breitenbach and others 1965; Hill and Robertson 1988). However, our observations (days required to verify incubation) showed that hens at TLNWR did not begin incubation as intensively (no movement while on eggs) and appeared more restless than hens at LKNWR in both nesting seasons. Persson and Göransson (1999) reported that nest attendance was dependent on the physical condition of the hens; those in good condition had higher nest attendance. The multiple pieces of evidence from this study (small hens, reduced nesting and renesting, small clutch sizes, and restlessness at the beginning of incubation) suggest that the TLNWR hens may be nutritionally stressed.

The pheasant populations at TLNWR and LKNWR were greatly reduced from historical numbers (Hart and others 1956; Zezulak 1990), particularly during the last winter of our study (1992 to 1993) when no radio-tagged hens survived. Above-normal precipitation with snowfall >51 cm flattened existing cover, including the marsh, forcing pheasants to take refuge in pump-station platforms, stacks of irrigation pipe, and open farm buildings. The birds were vulnerable to predation by mammalian and avian predators, especially eagles, hawks, and owls. On 28 December 1992, we observed several golden eagles, red-tailed hawks (*Buteo jamaicensis*), marsh hawks (*Circus cyaneus*), and rough-legged hawks (*B. lagopus*) perched around a stack of irrigation pipe sheltering approximately 50 pheasants during a severe snow storm. We were approximately 15 m from the stack of pipe, yet the pheasants did not flush (presumably because of the proximity and number of raptors present). Zezulak (1990) reported 3 previous years with snow cover >51 cm that resulted in significant declines in the pheasant harvest the following year. An extremely low harvest of 3 roosters in 1993 on refuge lands further supports the contention that the winter of 1992 to 1993 greatly reduced the pheasant population. Thus, hard winters with excessive snowfall undoubtedly influence pheasant numbers in the Klamath Basin, but if other conditions are adequate, pheasant populations with their high biotic potential should rebound (Smith 1966; Burger 1988; Newton 1998). This was not the case at TLNWR and LKNWR, where the pheasant population had yet to recover (even to 1992 numbers) 5 years after the harsh winter of 1992 to 1993 (David Mauser, Klamath Basin National Wildlife Refuge Complex, Tulelake, CA, pers. comm.).

## Management Implications

Though not specifically the subject of federal management efforts because of their exotic status, pheasants can be used as a sentinel for other avian species (for example, waterfowl and sparrows) to evaluate the general health of the systems at both TLNWR and LKNWR. Pheasants living at TLNWR were in poor condition with all evaluated characteristics being below normal. The TLNWR pheasant population (and to a lesser extent that at LKNWR) has marginal cover, especially in the winter and spring when most mortality of adult pheasants occurred due to predation and in the early spring when nesting attempts generally failed. Adult mortality rates in 1991 were toward the high end of those reported in the literature; however, the observed loss of 100% of radio-tagged hens during the winter of 1992 to 1993 (severe winter with heavy snows) demonstrated the impacts of inadequate vegetative cover. Residual cover at TLNWR should be expanded away from dikes and drains toward field edges to reduce predation on adults, nests, and young. Habitat management on the edge of agricultural crops should feature perennial grass and legume cover (Riley and others 1998). This cover, if left undisturbed, would establish residual cover for the next season. Small tracts of land could be interspersed throughout the agricultural fields to provide alternative cover for wildlife. A small field along "A" dike (approximately 5 ha) where hay swathers destroyed pheasant nests also contained a large number of duck nests. Adding permanent cover along field edges would also help farmers restrict seed dispersal of economically important weeds (*Bassia* sp. and *Kochia* sp.) by providing a barrier along field edges (Moonen and Marshall 2000). These habitat improvements would potentially benefit both wildlife and agriculture in these refuges.

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