AN ABSTRACT OF THE THESIS OF

David M. Mauser for the degree of Doctor of Philosophy in
Wildlife Science presented on December 9, 1991

Title: Ecology of Mallard Ducklings on Lower Klamath
National Wildlife Refuge, California

Redacted for Privacy

Abstract approved:
Robert L. Jarvis

The ecology of female mallards (*Anas platyrhynchos*) and their broods was studied during 1988-90 on Lower Klamath National Wildlife Refuge, California. Survival of 127 radio-marked ducklings from 64 broods was 0.18 to 10 days of life, and 0.37 and 0.34 to fledging for 1988, 1989, and 1990, respectively. For the 3 years of the study, 49.2% of hens lost their entire brood; 81.2, 36.8, and 37.5% in 1988, 1989, and 1990, respectively. Ninety-three percent of mortality occurred on or before 10 days of life. No significant differences were detected in the proportion of radio-marked ducklings lost from early hatched or late hatched nests. A variety of predators consumed radio-marked ducklings; however, 49% of the cases of mortality were a result of an unknown predator. During 1989 and 1990, 3 radio-marked ducklings from 16 hens which appeared to lose their entire brood were fledged by other brood hens, and of 29 radio-marked ducklings that reached 44 days of life, 6 (20.7%) had joined other broods.

Movements, home range, and habitat use were determined for 27 radio-marked broods. Relocation movements (>1000 m in 24 hrs) occurred in 12 of the 27 broods, primarily in the first week and after the fourth week of life. In 1989, significantly fewer radio-marked ducklings from broods hatching in permanent marshes survived to fledge compared to those originating in seasonal wetlands. Mean size of home ranges was 1.27 ± 0.47 km^2 and 0.62 ± 0.21 km^2 in 1989 and 1990, respectively. Most habitat selection by brood rearing hens occurred at the second order, (selection of home range area). Hens selected seasonally flooded wetlands with a cover component and avoided open or permanently flooded habitats.

Estimated recruitment (females fledged/adult female in the spring population), proportional change in population size, and number of fledged young varied markedly during the 3 years of the study. Estimated recruitment was 0.31, 1.26, and 0.83 for 1988, 1989, and 1990, respectively. The estimated proportional change in population size ranged from 0.73 in 1988 to 1.29 and 1.04 during 1989 and 1990, respectively. Number of fledged young ranged from 915 in 1988 to 6,102 in 1989. Movements, habitat use, and survival of postbreeding radio-marked mallard hens were also determined. From mid-April to early August, 5,279 exposure days without the loss of a radio-marked hen were tallied. Of the 4 hens which emigrated from the study area, all were unsuccessful in rearing a brood. Unsuccessful hens moved to surveyed areas north of the study area significantly sooner than successful hens. Canals were the primary habitat utilized by postbreeding hens in 1988 while mixed seasonal and emergent permanent marsh were the most frequently used habitats in 1989 and 1990. Open seasonal and mixed seasonal marshes were the most frequently utilized habitats by incubating hens. Radio-marked hens moved a mean distance of 1,350 m from the nest to suspected feeding areas.

ECOLOGY OF MALLARD DUCKLINGS ON LOWER KLAMATH NATIONAL WILDLIFE REFUGE, CALIFORNIA

by

David M. Mauser

A THESIS
submitted to
Oregon State University

in partial fulfillment of
the requirements for the
degree of
Doctor of Philosophy

Completed: December 9, 1991
Commencement: June 1992

APPROVED:

Redacted for Privacy

Robert L. Jarvis, Professor of Wildlife Ecology, in charge of major

Redacted for Privacy

Richard A. Tubb, Head of Department of Fisheries and Wildlife

Redacted for Privacy

Dean of Graduate School

Date thesis is presented: December 9, 1991

Typed by: David M. Mauser

ACKNOWLEDGEMENTS

The success of the study hinged on the involvement of many persons. I extend sincere appreciation to Robert L. Jarvis, my major professor, for his guidance through all aspects of the study and to my graduate committee; Robert G. Anthony, Cliff Pereira, David S. Gilmer, W. Bruce Shepard, and Jerry D. Hendricks. Hiram W. Li directed the research review and Bruce E. Coblentz contributed useful comments on the final report.

Several agencies provided financial support for the research including the Klamath Basin NWR complex (USFWS), Northern Prairie Wildlife Research Center (USFWS), the USFWS Region 1 office in Portland, and Oregon State University, Department of Fisheries and Wildlife.

Roger Johnson and his staff at the Klamath Basin NWR provided my salary, vehicles, equipment maintenance, and access to all portions of the study area. James Hainline and Ron Cole shared their knowledge of the Lower Klamath NWR and potential nesting and brood rearing areas. John Matthews and Ron Hellman maintained telemetry vehicles.

Dave Gilmer and his staff at the Dixon Field Station of the Northern Prairie Wildlife Research Center provided many of the radio transmitters and receivers used during the study and suggested improvements to the design of the study. Dennis Orthmeyer offered suggestions concerning the use of transmitters on ducklings and recommended several attachment methods.

I extend sincere appreciation to Brian Day, Ron Bielefield, Greg Golet, Warren Davis and Faye Weekley for the endless hours of superb

assistance they provided during the field seasons. The dedication of these individuals insured the success of the project. Several 4-legged field assistants were especially valuable in locating nests: Nubs, Shasta, and Niner.

My sincerest gratitude is extended to my wife Faye for her continuous support and our son Paul who helped put poverty and field work in perspective.

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PREFACE

The thesis is written as a series of manuscripts. This format was chosen to facilitate publication of results, thus enabling professionals in research and management to obtain the information in a timely manner. Because of this format, repetitive information exists among chapters; for this I apologize.

Because of the lack of information concerning the ecology of mallard broods, the study was largely observational; a logical first step toward understanding the ecology of mallard broods. The first 2 chapters deal with survival rates, agents causing mortality, home range, movements, and habitat selection by mallard broods. Questions about how survival of ducklings might impact the dynamics of the mallard population on the study area, prompted me to write Chapter III: Recruitment of mallards on Lower Klamath NWR. Chapter IV was written because of the paucity of information concerning postbreeding activities of mallard hens, and lastly, Chapter V describes the transmitter attachment procedure I developed for use on newly hatched mallard ducklings.

ECOLOGY OF MALLARD BROODS ON LOWER KLAMATH NATIONAL WILDLIFE REFUGE, CALIFORNIA

INTRODUCTION

The mallard (Anas platyrhynchos) is the most numerous, widely distributed (Bellrose 1976), and heavily harvested (Trost et al. 1987) duck species in North America. In addition to its value to hunters, the mallard has significant value to non-consumptive wildlife users (Johnsgard 1975). The mallard has been the subject of extensive research and has been used as an indicator of the health of many species of waterfowl (particularly dabblers) and their habitats. Unfortunately, mallard populations have reached record or near record low population levels through the mid-1980's (Reynolds 1987).

Reasons for the decline of mallards are multiple. The traditional explanation for the decline of mallards has been loss of wetland habitat in the prairie breeding areas of southern Canada and the north-central U.S. Wetland drainage in prime production areas is, without doubt, a reason for concern. Of the original 127 million acres of wetlands in the U.S., 52 million acres have been lost (Johnsgard 1975). In addition, prairie Canada has lost approximately 40% of its wetland acreage (Canada/United States Steering Committee 1986).

While loss of wetlands in the prairies has major impacts on breeding waterfowl, loss of upland nesting habitat may be equally serious. The original composition of prairie habitats has been essentially lost. The bison (Bison bison) has been replaced by domestic cattle and most uplands have been converted to crop production. This alteration of the ecosystem has resulted in a change in the original predator community (Brace et al. 1987). The wolf (Canis lupus) has been replaced by the coyote (C. latrans) and the red fox (Vulpes fulva). Red fox are especially damaging to upland nesting waterfowl, destroying nests and taking nesting hens (Sargeant et al. 1984). Nesting success of mallards across much of the prairie region is currently judged to be insufficient to maintain local populations (Greenwood et al. 1987).

The proportion of the continental mallard population breeding in prairie Canada has declined from 52% (1955 - 1965) to 44% (1976 - 1985) (Turner et al. 1987). This decline in the productively of the Canadian prairies increases the importance of production from other areas. Unfortunately, little is known of mallard production outside the prairie pothole region.

The Klamath Basin of southern Oregon and northern California is one of the major waterfowl production areas of the intermountain west (Jensen and Chattin 1964, Bellrose 1976). Nesting studies from this area (Miller and Collins 1954, Rienecker and Anderson 1960) have indicated high nesting success and high nest densities; however, the lack of reliable estimates of duckling survival have prevented accurate calculations of production. Johnson et al. (1987) noted that rates of brood and duckling losses are vital to an understanding of the population dynamics of the mallard.

A similar paucity of information exists concerning the spatial and habitat needs of broods. The habitat requirements of broods are especially important because habitat conditions may influence survival (Smith 1971). Most habitat studies of mallard broods have been conducted in the prairie pothole region of the United States and

Canada, where wetlands are interspersed among extensive areas of upland and aquatic connections among basins are often absent. In contrast, wetlands in the intermountain west are typically large systems of closely interspersed wetlands with aquatic interconnections and little intervening upland. Consequently, movements and selection of habitats by mallard broods in the intermountain west may be different than what has been reported in prairie environments.

Dispersal of waterfowl after the breeding season has hindered research (Fredrickson and Drobney 1977), resulting in a paucity of information on the postbreeding ecology of mallards. While several authors have described activities during the postbreeding period (Hochbaum 1944, Oring 1964, Salomonsen 1968), little information exists concerning habitats utilized by postbreeding pre-molting hens.

Since the development of modern methods of band recovery analysis (Brownie et al. 1985), survival rates of mallards have been extensively studied (Anderson 1975, Trost 1987, Chu and Hestbeck 1989). However, because most band recovery models yield only estimates of annual survival (Brownie et al. 1985), most investigators have been unable to estimate seasonal rates of survival (Blohm et al. 1987). Spring-summer survival of adult hens is especially important because hens killed during initial nest attempts are not available to renest. These after-second-year (ASY) hens lay large clutches (Swanson et al. 1986) and experience high nesting success (Cowardin et al. 1985).

Thus, while an extensive body of literature exists on the mallard, a paucity of information exists concerning both the brood rearing and the postbreeding period. As mentioned previously, the secretive nature of mallard broods and dispersal of postbreeding birds are the 2 major reasons for this lack of information.

The primary emphasis of this investigation was to determine survival rates and habitat use of mallard broods on Lower Klamath National Wildlife Refuge. Results of these investigations are reported in Chapters I and II. In order to obtain reliable estimates of duckling survival and monitor their habitat use, I developed a method to affix radio transmitters to newly hatched ducklings, a technique suggested by previous studies (Cowardin et al. 1985, Orthmeyer and Ball 1990). The transmitter attachment method is described in Chapter V.

In Chapter IV, I calculated estimates of recruitment of mallards from Lower Klamath NWR using a combination of results from this study, data gathered by the refuge staff, and published results from other studies. This analysis was important because it addressed the question of whether natality was adequate to replace mortality. Methodology and results from this aspect of the study are reported in Chapter IV.

Once the study was initiated, I discovered that hens which had completed their breeding activities remained near the study area, thus, allowing me an opportunity to describe postbreeding activities and habitat use. A report of these findings is included in Chapter III.

CHAPTER I SURVIVAL OF MALLARD DUCKLINGS

INTRODUCTION

Recruitment is a major force governing mallard (*Anas platyrhynchos*) populations and can be divided into 2 parts: hen success (a function of nest success) and duckling survival (Cowardin and Johnson 1979). While extensive research has been conducted on nesting ecology (see Bellrose 1976 for accounts by species), few reliable estimates of duckling survival exist. This paucity of information is a result of the secretive nature of mallard broods and the tendency for ducklings to intermix among broods. Cowardin et al. (1985) indicated that survival of ducklings from hatching to fledging is probably the least understood component of recruitment, while Johnson et al. (1987) noted that rates of brood and duckling losses are vital to an understanding of the population dynamics of the mallard.

Loss of all ducklings in mallard broods (total brood loss) is known to account for a significant proportion of total mortality (Ball et al. 1975, Reed 1975). Of the recent studies which have incorporated total brood loss, survival estimates of ducklings from hatching to fledging have ranged from 0.35 (Talent et al. 1983) to 0.68 (Lokemoen 1990).

Three major techniques have been used to estimate survival of ducklings: mark-recapture (Reed 1975, Haramis and Thompson 1984), the observed attrition of ducklings from broods (Keith 1961, LaHart and Cornwell 1970, Stoudt 1971), and the use of radio-marked brood hens (Ball et al. 1975, Talent et al. 1983, Orthmeyer and Ball 1990). With mark and recapture methods, it is difficult to mark a sufficient proportion of the population, and the capture of ducklings can result in disruption of the brood bond. Survival estimates from brood observations rely on the proportion of ducklings lost from broods compared to the number of ducklings at hatch. However, broods from which all ducklings have been lost are not accounted for and consequently, survival of ducklings is overestimated (Reed 1975, Ringelman and Longcore 1982). Use of radio-marked hens was largely responsible for documenting the extent and importance of total brood loss; however, these studies must assume that ducklings missing from a brood lead by a radio-marked hen, have died. In addition, visual relocation of radio-marked brood hens to count ducklings often results in excessive disturbance which may affect survival probabilities and habitat use. Dzubin and Gollop (1972) and Duncan (1986) speculated that broods of newly hatched young may be especially susceptible to disturbance.

Specific agents of duckling mortality are largely speculative or anecdotal accounts of isolated acts of predation (Keith 1961, Dwernychuk and Boag 1972, Duncan 1986). In addition to predation, ducklings are known to die of exposure (Keith 1961, Reed 1975, Seymour 1982). Orthmeyer and Ball (1990) concluded that an understanding of the agents of duckling mortality were required before specific management strategies could be implemented, and that radio-marking of ducklings was the best method for acquiring this information.

I have attempted to overcome many of the difficulties of studying mallard broods by radio-marking both the brood hen and 2 ducklings per brood. This allowed me to monitor broods without disturbing them and determine the fate of individual radio-marked ducklings. The objectives of the research were to determine the survival of mallard ducklings from hatching to 50 days of age and to determine the agents causing death of radio-marked ducklings.

STUDY AREA

The study took place on the Lower Klamath National Wildlife Refuge (NWR), Siskiyou County, California. The elevation of the refuge is approximately 1,220 m and refuge habitats encompass 19,500 ha of seasonal and permanent marshes, barley fields, uplands, and canals. Water was removed from seasonal marshes leaving them dry from late spring/early summer to fall, thus encouraging the germination of desired plant species and maximizing aquatic invertebrate abundance. These units were reflooded during the fall, thus making seeds available to fall migrant waterfowl. Management of seasonal units follows the principals described by Fredrickson and Taylor (1982). The refuge is managed primarily for fall and spring migrant waterfowl and secondly for waterfowl production.

METHODS

Field work was conducted from 1 April - 20 August during 1988, 1989, and 1990. Mallard nests were located using both trained dogs and chain drags stretched between all-terrain cycles (ATCs). Limitations of manpower forced me to search predominantly thick cover, habitats frequently utilized by nesting mallards (Lokemoen et al. 1990). Approximately 2 hrs were spent searching each area; thus, high nest density areas tended to contribute more nests to the sample than low density areas. Areas searched included emergent marshes, islands, uplands and levee banks.

Once nests were located, eggs were candled (Weller 1956) to determine stage of incubation and to predict hatching dates. At 18-20 days incubation, hens were captured on nests using long handled dip nets and nest traps (Weller 1957). Each captured hen was weighed to the nearest 5 g and fitted with a 22-25 g backpack radio transmitter (AVM Instrument Co., Livermore, Calif.) using a Dwyer (1972) harness. The number 2 secondary covert feather was removed for use in age determination (1 year old or >1 year old; Krapu et al. 1979), and standard USFWS aluminum leg bands were affixed. Nasal saddles (Doty and Greenwood 1974) were attached to all hens in 1988 but were not used in 1989 and 1990.

On the date of hatch, 1.9 - 2.1 g radio transmitters were affixed to 2 ducklings in each brood using the method described by Mauser and Jarvis (1991). Most ducklings were still wet or lacked full mobility when marked; thus, they did not disperse from the nest upon completion of the procedure. Transmitters were approximately 5-7% of initial body mass and had a battery life of 50-60 days.

Radio-marked broods and hens were monitored with truck-mounted 5-element null detection systems and were located 1 to 4 times daily. In addition, selected broods were monitored continuously for 1-3 hour time blocks during the early morning or late evening.

Ducklings were assumed dead if the transmitter was ingested by a predator, recovered and physical evidence indicated mortality, or if the signal from a duckling transmitter was lost and visual observation indicated the duckling was absent from the brood. Ducklings were censored (Anderson et al. 1980:200) from analysis if erratic transmitter signals proceeded a loss of contact with the marked duckling. Censored ducklings were considered at risk until the time of censoring at which time the sample of marked ducklings at risk was reduced by 1. It was assumed that censoring was independent of the fate of the duckling (Pollock et al. 1989).

To ascertain whether transmitters were negatively affecting ducklings, counts were made of the number of marked and unmarked ducklings lost from within broods. Counts were obtained opportunistically to avoid disturbance of broods. To compare the proportion of marked and unmarked ducklings lost, a simple pooling of data across broods and years would be inappropriate because the probability of being lost is likely to vary greatly from year to year and brood to brood. Instead, broods within years were treated as strata and the marked vs. unmarked proportions were compared using the Mantel-Haenszel (M-H) statistic and test for comparing odds ratios (Anderson et al. 1980). Within a stratum (brood within year) the odds ratio (marked-tounmarked) is defined as the odds of being lost in the marked group ($P_m/(1-P_m)$) divided by the odds of being lost in the unmarked group ($P_u/(1-P_u)$). Note that when the odds ratio is 1, then $P_u=P_m$. The M-H procedure allows one to test whether the odds ratio is the same in all strata and then whether the common value of the odds ratio differs from 1. Because of the small numbers per stratum (brood within year), the statistical software program STATXACT (Cytel Software Corp., Cambridge, Massachusetts) was used to calculate exact rather than asymptotic (large sample) p-values and confidence intervals.

The method proposed by Kaplan and Meier (1958) and further described by Pollock (1989) was used to estimate survival of radio-marked ducklings. Survival was estimated from the date of hatch to 50 days of age. The Kaplan-Meier method is a non-parametric method which makes no assumptions about the survival distribution. The method assumes that animals are sampled randomly, that the process of radio-marking has no affect on survival of the animal, and that survival probabilities of individual animals are independent (Pollock et al. 1989).

The Kruskal-Wallis test (one-way analysis of ranks) was used to test the null hypothesis that the number of days survived by marked ducklings within the same brood were independent. Because of the large number of ties in ranks and the small number of marked ducklings within broods, p-values were estimated from 8,000 to 20,000 Monte Carlo simulations using STATXACT (Cytel Software Corp., Cambridge, Massachusetts).

A stratified (by year) Wilcoxon rank sum statistic was used to determine whether the proportion of broods fledging 0, 1, or 2 marked ducklings from early (prior to 1 June) hatched broods was different than late (after 1 June) hatched broods. After a log transformation, simple linear regression was used to describe the 6-day survival function.

Cases of mortality were grouped into 1 of 3 categories (confirmed, probable, or unknown) based upon the certainty with which the agent causing mortality could be identified. Confirmed cases of mortality generally resulted from ingestion of the duckling and transmitter or from visual observation of a specific predator with a radio-marked duckling. A probable case of mortality was assigned when physical evidence (tracks, tooth marks, hair, feathers etc.) indicated a specific predator or a class of predators. Mortality was classified as being from unknown agents when transmitter signals were abruptly lost and a marked duckling was absent from the brood, or when too little evidence was present at the site of mortality to determine the cause of death.

RESULTS

Survival of radio-marked ducklings

A total of 127 ducklings from 64 broods were radio-marked during the study. Eighteen broods and 36 ducklings, 21 broods and 41 ducklings (in 1 brood 1 duckling was marked), and 25 broods and 50 ducklings were marked in 1988, 1989, and 1990, respectively. In 1988, unreliable transmitters restricted the estimate of survival to the initial 10 days of life. Estimated survival was 0.181, 0.366, and 0.344 for 1988, 1989, and 1990, respectively (Table I.1).

The null hypothesis of independence of ducklings within broods was rejected for 1989 and 1990 ($\underline{P} = 0.0001$ and $\underline{P} = 0.043$, respectively), and was nearly rejected for 1988 ($\underline{P} = 0.055$). I believe that the statistical tests reinforce biological intuition; ducklings within the same brood experience similar environmental conditions and predator communities, thus probabilities of survival were related. While survival probabilities of the 2 marked ducklings within the same brood were not independent, neither were they totally dependent. If survival within a brood were completely dependent, one would expect both marked ducklings from the same brood to either die on the same day or survive. However, in 12 broods from 1989 and 1990, 1 of 2 radio-marked ducklings survived to fledge, indicating that survival was not completely dependent. Because of the dependence of survival probabilities of marked ducklings within broods, the standard deviation reported (based on independence) is likely a lower bound on the true standard deviation.

In 1989 and 1990, 93% (54 of 58) of the mortality occurred on or

Table I.1. Kaplan-Meier survival estimates for radio-marked mallard ducklings from Lower Klamath NWR, 1988-90. Standard deviations are reported assuming the probability of survival among radio-marked ducklings within a brood were independent.

Year	N	Survival	SD
1988	36	0.181[a]	0.067
1989	41	0.366	0.092
1990	50	0.344	0.072

[a] Estimated survival to 10 days of life.

before 10 days of life with 86% (50 of 58) occurring prior to 6 days (Fig. I.1). The survivorship curve for the period from hatching to 50 days of age was log transformed. The survival function for the first 6 days of life (Fig. I.1) indicated a relatively constant percentage of radio-marked ducklings dying (or surviving) per day: 24.5, 16.1, and 13.6% for 1988, 1989, and 1990, respectively.

Of the 87 ducklings known to have died, 16 deaths (18.4%) occurred while broods were moving from nest to water. All other mortality occurred in rearing marshes or during moves among wetlands. For the 3 years of the study, 49.2% of radio-marked hens, for which fates could be determined, lost their entire broods: 81.2% (13 of 16) in 1988, 36.8% (7 of 19) in 1989, and 37.5% (9 of 24) in 1990. Of the 16 hens in 1989 and 1990 which appeared to lose their entire brood, 3 marked ducklings from 2 of these radio-marked hens were reared to fledging by other brood hens.

Of the 91 radio-marked ducklings hatched in 1989 and 1990, 12 (13.2%) joined other broods, and of 29 radio-marked ducklings that reached 44 days of life, 6 (20.7%) had joined other broods. These 6 ducklings were separated from their natal hens at 2, 18, 18, 19, 22, and 39 days, respectively. Five ducklings joined mallard broods and 1 joined a pintail (A. acuta) brood.

Using the stratified Wilcoxon rank sum test, no significant difference was detected in the proportion of broods fledging 0, 1, or 2 radio-marked ducklings from early hatched ($n = 16$ in 1989 and $n = 17$ in 1990) or late hatched nests ($n = 3$ in 1989 and $n = 6$ in 1990) ($P = 0.739$). During 1989 and 1990, 6 second-year (SY) females which hatched a brood were radio-marked; 4 of these hens fledged radio-marked

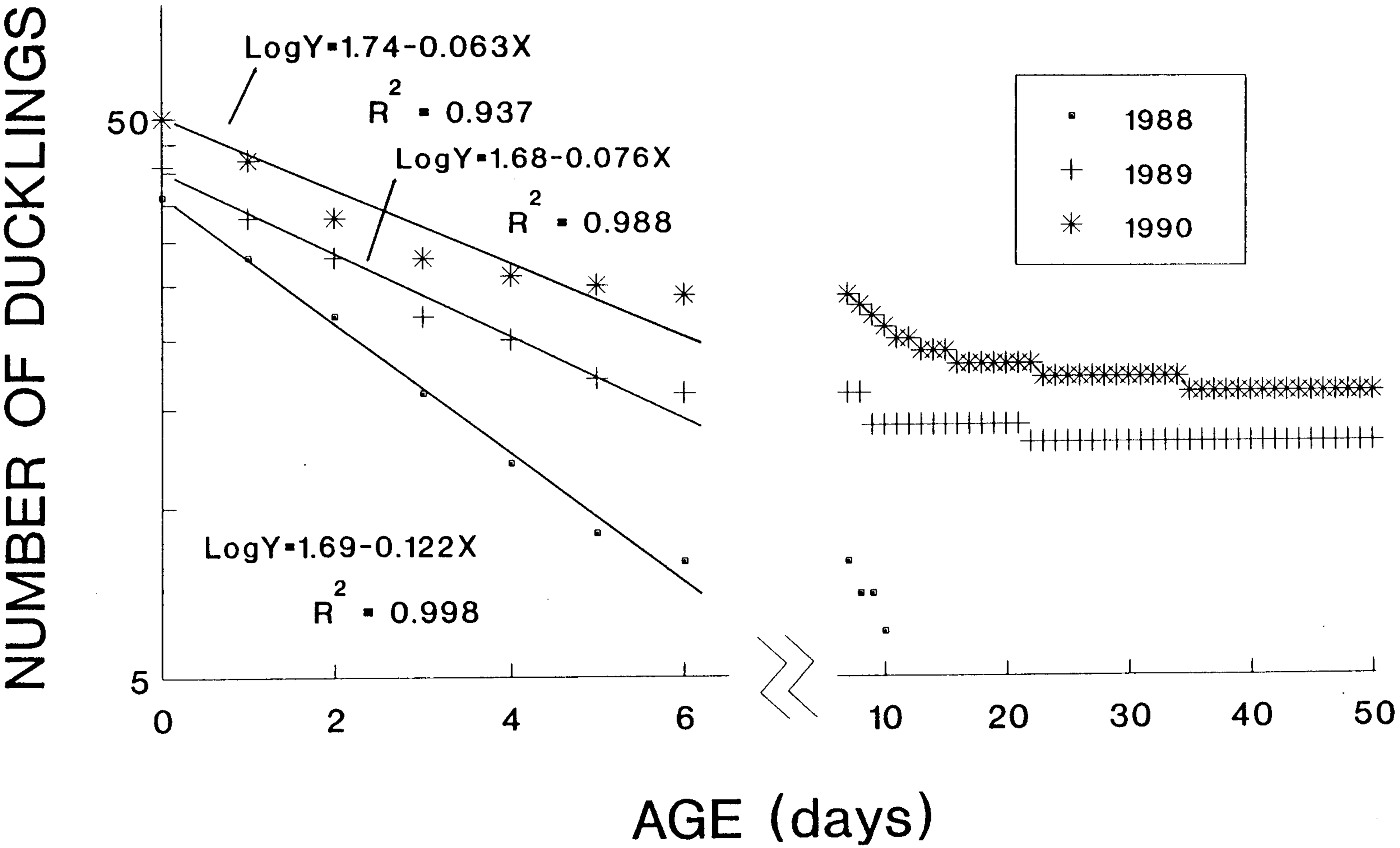


Fig. I.1. Regression analysis for initial 6-days of life and survival function for remainder of fledging period for radio-marked mallard ducklings from Lower Klamath NWR, California, 1988-90. Number of ducklings (y-axis) in log scale.

ducklings. The small sample size precluded statistical comparison to after second-year (ASY) hens.

Effects of transmitters on ducklings

A principal assumption in estimating the survival rates of ducklings was that transmitters did not affect survival. Tests of the homogeneity of odds ratios among years indicated no significant difference ($\underline{P} = 0.964$). Nineteen of the 64 mallard broods marked during the 3 years of study were re-sighted when <12 days old, and 20 of the 38 marked ducklings and 59 of the 122 unmarked ducklings were lost. These proportions resulted in an estimated odds ratio which was not significantly different than 1 (odds ratio = 1.29, 95% CI = 0.577,2.946, $\underline{P} = 0.672$). While the power of the test was low, the estimated odds ratio suggests that transmitters had little effect on survival of mallard ducklings.

Causes of duckling mortality

A variety of predators consumed radio-marked ducklings (Table I.2) with 26.4% attributed to avian predators and 14.9% to mammalian predators. Long-tailed weasels (*Mustella frenata*) were abundant on Lower Klamath NWR and took more ducklings than all other confirmed mammalian predators combined (Table I.2). All cases of death attributed to exposure (8) occurred prior to 4 days of life and usually occurred during periods of spring snow storms, or when predators dispersed a brood and the hen was unable to relocate her ducklings. In 2 cases, transmitters were known to be ingested by predators: a black-

Table I.2. Agents causing mortality of radio-marked mallard ducklings from Lower Klamath NWR, California, 1988-90. C = confirmed agent of mortality, P = probable agent, and U = unknown agent.

	1988			1989			1990			
Cause of mortality	C	P	U	C	P	U	C	P	U	Total
Avian										
Great-horned Owl					1					1
Northern Harrier		2		1						3
California gull				1						1
Black-crowned Night Heron				1						1
Unknown Raptor					3			1		4
Unknown Bird					7			6		13
Subtotal		2		3	11			7		23
Mammalian										
Coyote								1		1
Long-tail Weasel	1	1		1	3		2			8
Mink								2		2
Unknown Mammalian								2		2
Subtotal	1	1		1	3		2	5		13
Exposure				2			6			8
Unknown			25			5			13	43
Total	1	3	25	6	14	5	8	12	13	87

crowned night heron (*Nycticorax nycticorax*) and a California gull (*Larus californicus*). Both transmitters continued to function from inside these birds.

DISCUSSION

I assumed that transmitters on ducklings and hens had no effect on behavior or survival probabilities. Evidence collected concerning duckling survival, indicated little or no impact. Little information was gathered on radio-marked hens because of my desire to avoid disturbing broods. Gilmer et al. (1974) found that breast-mounted transmitter packages had a negligible impact on mallard hens, and in other studies mean brood sizes among radio-marked and unmarked hens were not different (Ball et al. 1975, Orthmeyer and Ball 1990). Marking of hens at 18-20 days incubation allowed 6-8 days for hens to become accustomed to transmitters prior to hatching of the clutch.

Survival of radio-marked ducklings

The survival rates obtained in 1989 (0.366) and 1990 (0.344) are comparable to those reported from other areas; 35% in North Dakota (Talent et al. 1983), 39.5% in Montana (Orthmeyer and Ball 1990), and 44% in Minnesota (Ball et al. 1975). However, Lokemoen et al. (1990) reported a survival rate of 68.1% for mallard ducklings in North Dakota based on differences in return rates from ducklings marked at the nest and pre-fledglings marked at a mean age of 44.6 days. The survival rate of 0.181 from 1988 is considerably lower than that reported in other studies.

The low survival rate in 1988 may have been due to habitat conditions and a late hatch caused by several periods of snow during April and May. During 1988, all seasonal marshes were largely dry by late April, prior to the peak of the mallard hatch. In addition, water was removed from 2 large permanent marshes during this same time period. The reduction in brood rearing areas may have exposed ducklings to high rates of predation. Changes in water management in 1989 and 1990 resulted in all seasonal marshes remaining full through early June, thus dispersing broods and reducing losses to predators. Approximately 70% of the wetlands on Lower Klamath NWR are seasonal marshes.

As in other studies, the loss of entire broods was high: 81% in 1988, 37% in 1989, and 38% in 1990. Loss of entire broods, however, may be somewhat misleading as at least some ducklings from "lost broods" were adopted into other broods and reared to fledging. The incidence of brood switching may have been inflated because of the high density of mallard broods and their concentration on a reduced wetland base during late spring and early summer. Adoption of ducklings by unrelated hens may increase in prevalence as managers attempt to increase production on small areas.

Mortality of ducklings at Lower Klamath NWR was initially high (93% <10 days of age) but decreased rapidly after 10 days of age. This same pattern has been noted previously, although the proportion of mortality occurring early in life was higher at Lower Klamath NWR than in other areas. The proportion of total mortality varied from 70% in the initial 2 weeks of life (Ball et al. 1975) to 87% in the first 18 days of life (Orthmeyer and Ball 1990). Differences in the timing of mortality was probably due to different physical, climatic, or biological attributes among respective study areas.

Orthmeyer and Ball (1990) found that late hatched (after 10 June) broods experienced lower survival rates than early hatched broods.

While sample sizes were small, such differential survival did not appear to occur at Lower Klamath NWR. Late hatched nests may not have experienced lower survival rates because June is the main hatching period for gadwalls (*A. strepera*), the most numerous nesting duck on the study area. Gadwall ducklings may provide a source of alternative prey, thus reducing predation on mallard ducklings. Pehrsson (1986) found that production of oldsquaw (*Clangula hyemalis*) broods and ducklings were highest in years of peak rodent populations, indicating that alternative prey may be important in reducing impacts of predation in some areas.

Very little mortality of ducklings occurred during the initial move from nest to water, probably because mallards nested close to water ($\overline{x}$ = 31.8 m, n = 63, range = 0 - 200 m). Talent et al. (1983) found that no loss of entire mallard broods occurred during overland travel and that mortality occurred in marshes. However, Dzubin and Gollop (1972) estimated that 52% of mallard broods perished during the initial move from nest to water on their Canadian study area. Ball et al. (1975) found a negative correlation between distance moved by broods and subsequent survival and suggested that most losses occurred during overland moves. Again, inherent differences among study areas or different methodologies may explain discrepancies among results.

Causes of duckling mortality

The primary objective of the study was to estimate survival, therefore, I marked as many hens and ducklings as feasible. Although this resulted in smaller amounts of time spent with individual broods, it is doubtful that improved vigilance would have increased the quantity of data because predators often took ducklings at night or in dense cover where predation was unobservable.

Because a large proportion of the cases of mortality were classified as unknown, it is difficult to draw conclusions concerning specific predators. Avian predation made up the largest proportion of the confirmed and probable cases of mortality; however, birds are readily observable and rarely damaged transmitters making kill-sites easy to locate. Conversely, mammals may have chewed transmitters rendering them inoperable, thereby contributing to the large proportion of cases classed as unknown.

Mink (M. vison), an implicated predator of ducklings in North Dakota (Talent et al. 1983), were uncommon on Lower Klamath NWR (J. Hainline, Klamath Basin NWR, pers. commun.) and did not appear to be an important predator. Weasels generally took ducklings during overland moves, either while moving from nest to water or when crossing upland areas between wetlands. The high proportion of avian predators implicated may have resulted from several large nesting colonies of black-crowned night herons and great egrets (Casmerodius albus), and a high population of nesting raptors, including red-tailed hawks (Buteo jamaicensis), great-horned owls (Bubo virginianus), short-eared owls (Asio flammeus), northern harriers (Circus cyaneus), and barn owls (Tyto alba) on or near Lower Klamath NWR.

CONCLUSION

While mortality rates of ducklings on Lower Klamath NWR were high, the wide variety of predators consuming ducklings make predator control both an unacceptable and an ultimately unsuccessful solution. In addition, many of the implicated predators have high aesthetic values. The best solution for increasing duckling survival probably lies in providing improved habitat conditions. The low survival rate experienced in 1988 was likely a result of a small habitat base available for broods, especially seasonally flooded habitats, the preferred habitat of broods on Lower Klamath NWR (Chapter II).

The high mortality rate of ducklings early in life increases the importance of providing quality habitat to broods during this time period. This is especially important in areas where wetland managers are able to manipulate water levels. If water must be removed from wetlands, it should be accomplished after mallard broods are >2 weeks old.

The high incidence of ducklings changing broods on Lower Klamath NWR should be of concern to managers or researchers concerned with estimating production, especially from high brood density areas. As managers attempt to increase production from reduced acreages, the interchange of ducklings among broods will increase the difficulty of estimating production. In addition, the concept of total brood loss may lose significance in high density brood areas. Ducklings lost from one brood may be accepted into other broods or survive alone.

The present study was largely observational. Further research of an experimental nature is needed concerning the effect of age and condition of brood hens on duckling survival. In addition, the effect of different habitats on survival represents another gap in our knowledge. Depending on water conditions, mallard broods are known to prefer seasonal or semi-permanent wetlands (Talent et al. 1982). Unfortunately, these are also the most readily drained for other uses. The impact of this practice on the survival of mallard broods or ducklings remains unknown.

CHAPTER II HABITAT USE, MOVEMENTS, AND HOME RANGE OF MALLARD BROODS

INTRODUCTION

Proper management of mallard (Anas platyrhynchos) populations requires an understanding of spatial and habitat needs during all stages of the life cycle. The habitat requirements of broods are especially important because habitat conditions may influence survival (Smith 1971). Survival of ducklings is a major component of recruitment (Cowardin and Johnson 1979).

Many features have been suggested as key components of mallard brood habitat, including food resources (Talent et al. 1982), wetland size (Berg 1956, Keith 1961, Stoudt 1971, Smith 1971), amount of shoreline (Annon. 1980), presence of loafing areas (Beard 1964), permanence of flooding (McKnight 1969), and the presence of emergent vegetation (Smith 1971, Annon. 1980). Most studies have relied upon brood surveys to determine habitat use; however, the secretive nature of mallard broods (Talent et al. 1983) makes conclusions from these studies tenuous.

Mallard broods are highly mobile (Evans et al. 1952, Berg 1956, Keith 1961, Talent et al. 1982). Most movements by broods occur during the first 1-2 weeks of life (Talent et al. 1982) and the frequency and length of such movements are a function of the abundance and proximity of nearby wetlands (Keith 1961, Talent et al. 1982). Broods move for a variety of reasons. Stoudt (1971) and Talent et al. (1982) felt that broods moved to locate adequate food resources while Berg (1956) reported that broods moved to more permanent wetlands. Avoidance of predators and human disturbance have also been cited as reasons for the movements of broods (Stoudt 1971).

Most previous habitat studies of mallard broods have been conducted in the prairie pothole region of the United States and Canada, where wetlands are interspersed among extensive areas of upland and aquatic connections among basins are often absent. In contrast, wetlands in the intermountain west are typically large systems of closely interspersed wetlands with aquatic interconnections and little intervening upland. Consequently, movements and selection of habitats by mallard broods may be quite different than in prairie environments.

The objectives of this study were to determine the home range, movements, and habitat use of radio-marked mallard broods. Lower Klamath National Wildlife Refuge (NWR) provided an excellent area to study mallard broods. Nest success was high, a variety of wetland habitats were potentially available to broods, and an extensive road/dike system provided easy access for researchers.

STUDY AREA

The study took place during the spring/summer of 1988-90 on the Lower Klamath NWR located on the California-Oregon border at an elevation of 1,220 m. The area is located within the Klamath Basin 25 km south of Klamath Falls, Oregon and encompasses 19,500 ha of permanent and seasonally flooded marshes, uplands, barley (_Hordeum vulgare_) fields and an extensive system of canals and ditches. The water management regime on Lower Klamath NWR is artificially created and, thus differs significantly from the hydrology of the prairie pothole region. Permanent marshes on Lower Klamath NWR remain flooded throughout the year, similar to the prairies; however, seasonally flooded marshes are generally flooded in September-November and water is removed in May-June.

METHODS

Searching for nests was conducted from early April through mid-June. Methods utilized included searching on foot both with and without the use of dogs, and the use of a 50 ft (15.2 m) chain drag pulled by 2 all-terrain cycles (ATCs), similar in principal to the cable-chain device described by Higgins et al. (1969). Limitations of manpower forced me to search predominantly thick cover, habitats frequently utilized by nesting mallards (Lokemoen et al. 1990). Approximately 2 hrs were spent searching each area; thus, high nest density areas tended to contribute more nests to the sample than low density areas. Areas searched included emergent marshes, islands, uplands and levee banks.

Mallard hens were captured on nests using dip nets or nest traps (Weller 1957) at 18-20 days incubation and were then fitted with 22-25 g battery-powered radio transmitters using a Dwyer (1972) harness. On the date of hatch, radio transmitters were affixed to 2 ducklings in each brood using the method described by Mauser and Jarvis (1991). Broods were located 1-4 times daily: 4 times per day during the first 2 weeks of life, twice per day in the next 2 weeks, and once per day thereafter until 50 days of life. Broods were tracked using truck-mounted dual 5-element null detection systems. All locations were computed in the field using program XYLOG4 (Dodge and Steiner 1986) on Zenith 180 laptop computers. Program XYLOG4 uses the method of Lenth (1981) to calculate ninety-five percent confidence ellipses.

I recognize the limitations of using radio telemetry in studies of animal movements, home range, and habitat use. Point locations derived from triangulations are not exact (Springer 1979) and may be strongly influenced by topography or vegetation (Hupp and Ratti 1983). Lower Klamath NWR proved to be an ideal site for radio telemetry. The flat terrain and lack of trees minimized signal bounce, a potential source of error (Hupp and Ratti 1983), and the elevated levee roads provided almost line of sight access to transmitter signals. The complex of roads on the study area enabled me to locate most broods at distances of <1 km, usually <0.5 km. The short distances between receiver and transmitter usually resulted in calculated confidence ellipses of <0.5 ha.

Tests of the telemetry system (White and Garrott 1990:80) indicated that the standard deviation of error angle was <1° at 1 km distance from receiver to transmitter. Lee et al. (1985) felt that the standard deviation of error angle was the most appropriate measure of error. Triangulations of transmitters and radio-marked hens (on nests) at known locations indicated excellent accuracy.

Home Range

Home range was defined as the area in which broods restricted their activities during the rearing period (Odum and Kuenzler 1955). Home range size for mallard hens which fledged at least 1 duckling were calculated using the 95% minimum convex polygon method (Bowen 1982) with program HOMERANGE (Ackerman et al. 1990). The 95% polygon method excludes the 5% of the locations farthest from the calculated arithmatic center of the home range. Only locations having 95% confidence ellipses <1.0 ha were used for analysis. The number of locations from used to calculate home ranges of broods ranged from 35 to 97. Differences in mean home range size among years were tested with a t-test after a log transformation of the data.

Movements

Major moves were defined as straight line distances of >1,000 m between successive locations taken approximately 24 hr apart, usually from one morning to the next. Distances between transmitter locations were calculated with program HOMERANGE (Ackerman et al. 1990).

Habitat use

The vegetative cover and the proportion of area in water on the study area changed rapidly during the brood rearing period. I attempted to overcome this problem by dividing the brood period into an early (<7 June) and a late season (>7 June). Habitat preferences were determined for 15 broods during the early season and 23 broods during the late season (some broods were represented in both seasons). Broods in each season were a mixture of different ages. The early season included mostly young broods, while mostly older broods and some young broods from late hatches comprised the late season sample. I felt this was not a concern because dissimilar aged mallard broods are thought to have similar habitat preferences (Smith 1971).

Habitat preference was defined as the likelihood of an animal choosing a particular habitat among other equally available habitats and selection was defined as the process by which an animal chooses a particular habitat component (Johnson 1980). Habitat preference was determined at the second and third order within both early and late seasons using program PREFER (Johnson 1980). This method assumes that all individuals in the population have identical preferences, but is relatively insensitive to errors in determining availability of habitats (White and Garrott 1990) or subjective inclusions or exclusions of habitat components (Thomas and Taylor 1990). I felt that the rank order of available habitats remained constant within the early and late brood seasons even if the true proportions changed. Use/availability analysis was run by year and with both 1989-90 data combined. Because the number of sample units (broods) must exceed the number of habitat components (White and Garrott 1990), insufficient data were available for analysis from the late season of 1989.

The null hypothesis for second order selection was that the composition of habitats within home ranges was not different than the composition of habitats on the study area. Third order selection was indicated if habitats utilized by broods were different from proportions available within the home range. If null hypotheses were rejected, habitat preference/avoidance among specific habitat pairings were tested with the multiple comparison procedure of Waller and Duncan (1969).

Because habitat utilization within home ranges requires the assumption of independence of animal locations (White and Garrott 1990), only radio locations approximately 24 hr apart were used. I felt that locations >24 hrs apart were independent because broods were capable of reaching all areas of their home range within this time interval. To estimate third order selection, home ranges were determined for each brood with >20 independent locations (Swihart and Slade 1985) within each brood season. Because I considered the entire area within the outermost transmitter locations to be available, home range was estimated using the 100% minimum convex polygon method (Mohr 1947) with program HOMERANGE (Ackerman et al. 1990) and transferred to 7.5 minute orthophotoquads. Habitats were delineated on orthophotoquads and the area of each habitat on the study area and within home ranges were measured with a compensating polar planimeter.

Seven habitat types were defined based on water management regime and vegetative and/or structural characteristics; permanent emergent marsh (PEM), permanent open water (POW), seasonal open water (SOW), seasonal alkali bulrush (_Scirpus_ _maritimus_) (SAB), seasonal hardstem bulrush (_S_. _acutus_) (SHB), seasonally flooded uplands (SFU), and canals (CA). Seasonal habitats were wetland areas flooded <1 year (usually dry from June-September) and permanent marshes were flooded for >1 year. Two marshes on the east side of the study area had been flooded for 2 years (511 ha); all other permanent marshes (4) had been flooded for >5 years (2,049 ha).

Open water habitat types were devoid of emergent vegetation but often contained submergent plants or green algae. Seasonal hardstem bulrush and permanent emergent marshes were dominated by stands of hardstem bulrush with small quantities of cattail (_Typha_ _latifolia_) in some areas. Alkali bulrush marshes were generally dominated by near monotypic stands of this plant. Seasonally flooded upland areas contained a variety of grasses and forbes and resulted when new wetland impoundments were created or when normally dry upland areas were flooded by high water levels. CA had many of the attributes of seasonally flooded habitats; water levels fluctuated widely and high water often provided flooded vegetation on canal banks for broods. Because most of the canals on Lower Klamath NWR were adjacent to roads, I was able to accurately determine whether broods were utilizing a canal or an adjacent wetland. Within 1989 and 1990, the Wilcoxon rank sum test was used to determine if the proportion of broods fledging 0, 1 or 2 radio-marked ducklings which hatched in permanent marshes was different than for broods originating in seasonal marshes.

RESULTS

Because of unreliable transmitters and low survival of ducklings in 1988, insufficient data were available for home range, habitat, or movement analysis, thus only data from 1989-90 were utilized. Because most broods contained at least 1 radio-marked duckling, I did not require visual verification that the hen was leading a brood; thus, I believe that movement and habitat use of broods was not impacted by research activities. In fact, radio-marked broods were rarely observed and never disturbed.

Home range

Thirteen and 14 radio-marked mallard brood hens fledged at least one duckling in 1989 and 1990, respectively. Size of home ranges averaged 1.27 ± 0.47 km^2 (range 0.04-6.23 km^2) and 0.62 ± 0.21 km^2 (range 0.045-2.68 km^2) from 1989 and 1990, respectively. Size of home ranges were not significantly different among years ($\underline{t} = 1.17$, 25 df, $\underline{P} = 0.255$). While mean home range size was largest in 1989, mean number of locations was smaller ($\overline{x} = 71.6$) than in 1990 ($\overline{x} = 83.0$) indicating that sample size, within the range of the data, had little affect on home range size. Typically, home range size increases with sample size when using the minimum convex polygon method (White and Garrott 1990).

As expected, hens making relocation moves tended to have relatively large home ranges, often containing >1 activity center. Brood hens with small home ranges moved their broods to rearing areas and subsequently restricted their movements to relatively small areas.

Movements

Distances between locations of broods taken at 24 hr intervals probably do not completely represent daily movement patterns within home ranges (Laundre′ et al. 1987), but long distances between successive telemetry locations should be indicative of relocation movements of broods.

During 1989-90, relocation movements (>1,000 m) between successive 24 hr locations occurred in 12 of the 27 broods. Of these 12 broods, 7 made 1 major move, 3 made 2 moves, 1 made 3 moves, and 1 made 6 moves. Most moves occurred in either week 1 (6) of life or weeks 4 through 6 (16). Five of the 6 moves in the first week of life were to initial rearing areas with the remaining move occurring several days after a brood had reached a wetland area. All of these moves were made by hens moving broods away from nesting sites in or surrounded by permanent marshes to rearing areas in seasonally flooded habitats. No brood hens nesting in or adjacent to seasonal marshes made moves >1,000 m to initial rearing areas. Relocation moves in weeks 4-6 appeared to be in response to receding water levels in seasonal marsh rearing areas. The longest relocation move was 3.8 km in 24 hrs.

In 1989, of the 7 broods originating in permanently flooded marshes, none fledged radio-marked ducklings; however, of 14 broods originating in seasonal wetlands, 6 fledged 1 duckling and 4 fledged 2 marked ducklings. Using the Wilcoxon rank sum test, these differences were significant ($\underline{P} = 0.006$). In 1990, of the 7 broods hatching from permanent wetlands, 5 fledged 1 radio-marked ducklings and of 17 broods from seasonal wetlands, 4 fledged 1 marked duckling and 3 fledged 2 marked ducklings. In contrast to 1989, these differences were not significant ($\underline{P}$ = 0.520). All 14 brood hens associated with permanent marshes moved or attempted to move their broods out of these wetlands within 4 days of hatch.

Habitat use

Analysis of use/availability data by year yielded similar orders of preference of habitat components so data were pooled among years for analysis.

Second order selection

The null hypothesis that habitats within the home range were not different than those available on the study area was rejected for both the early ($\underline{F}$ = 16.89, 6,9 df, $\underline{P}$ = 0.0002) and late ($\underline{F}$ = 38.16, 6,17 df, $\underline{P}$ < 0.0001) seasons. Multiple comparison tests indicated many significantly different habitat pairings, with SHB, SFU, and CA being the most preferred habitats in both early and late seasons (Fig. II.1). In general, seasonal marshes with a cover component were preferred over permanent or more open habitat types.

Third order selection

The null hypothesis that habitats utilized by broods were not different than those available in home ranges was rejected for the late ($\underline{F}$ = 2.31, 6,17 df, $\underline{P}$ = 0.082, (significance level = 0.10)) but was not rejected for the early season ($\underline{F}$ = 1.84, 6,9 df, $\underline{P}$ = 0.197). This indicates either that broods in the early season were utilizing home

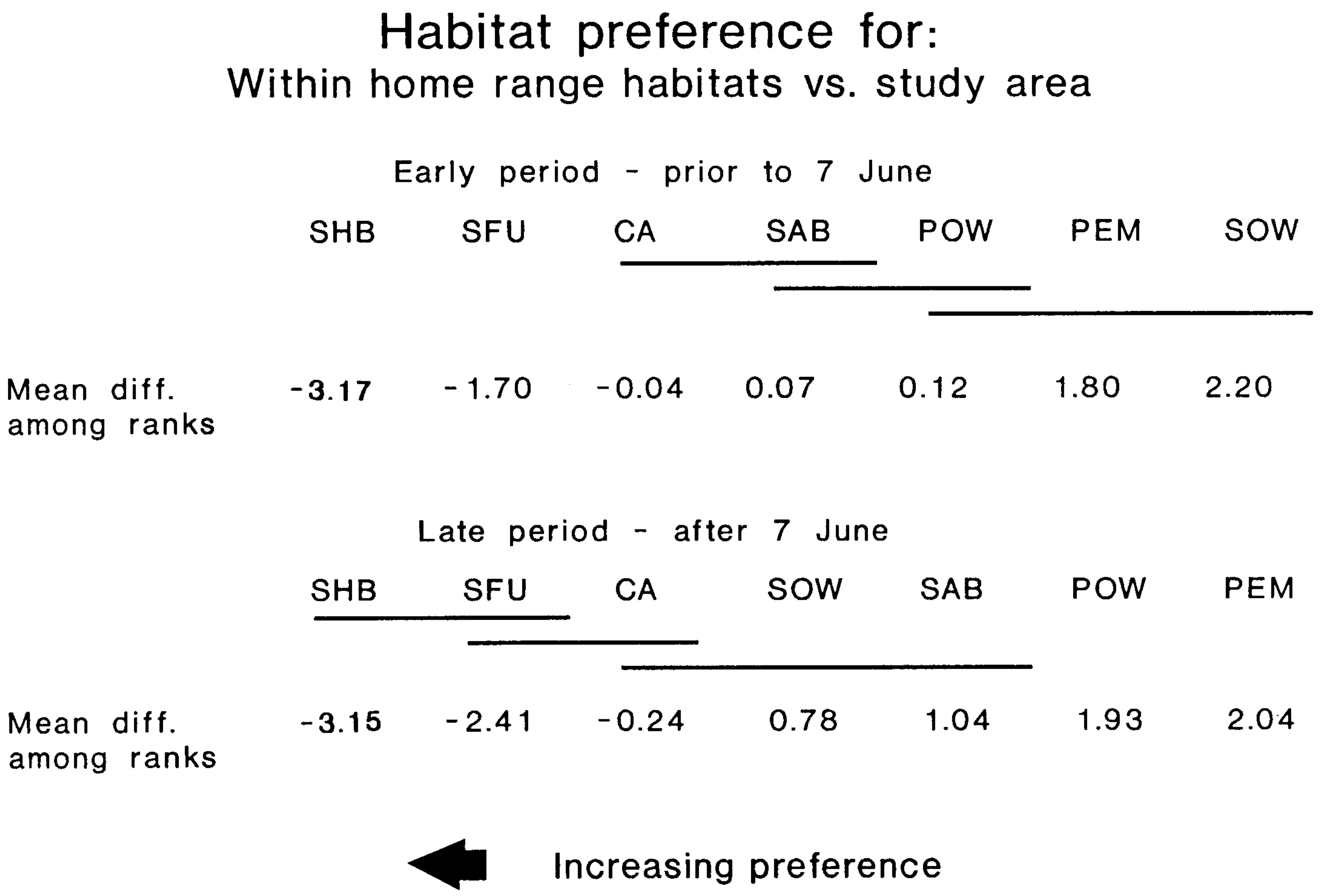
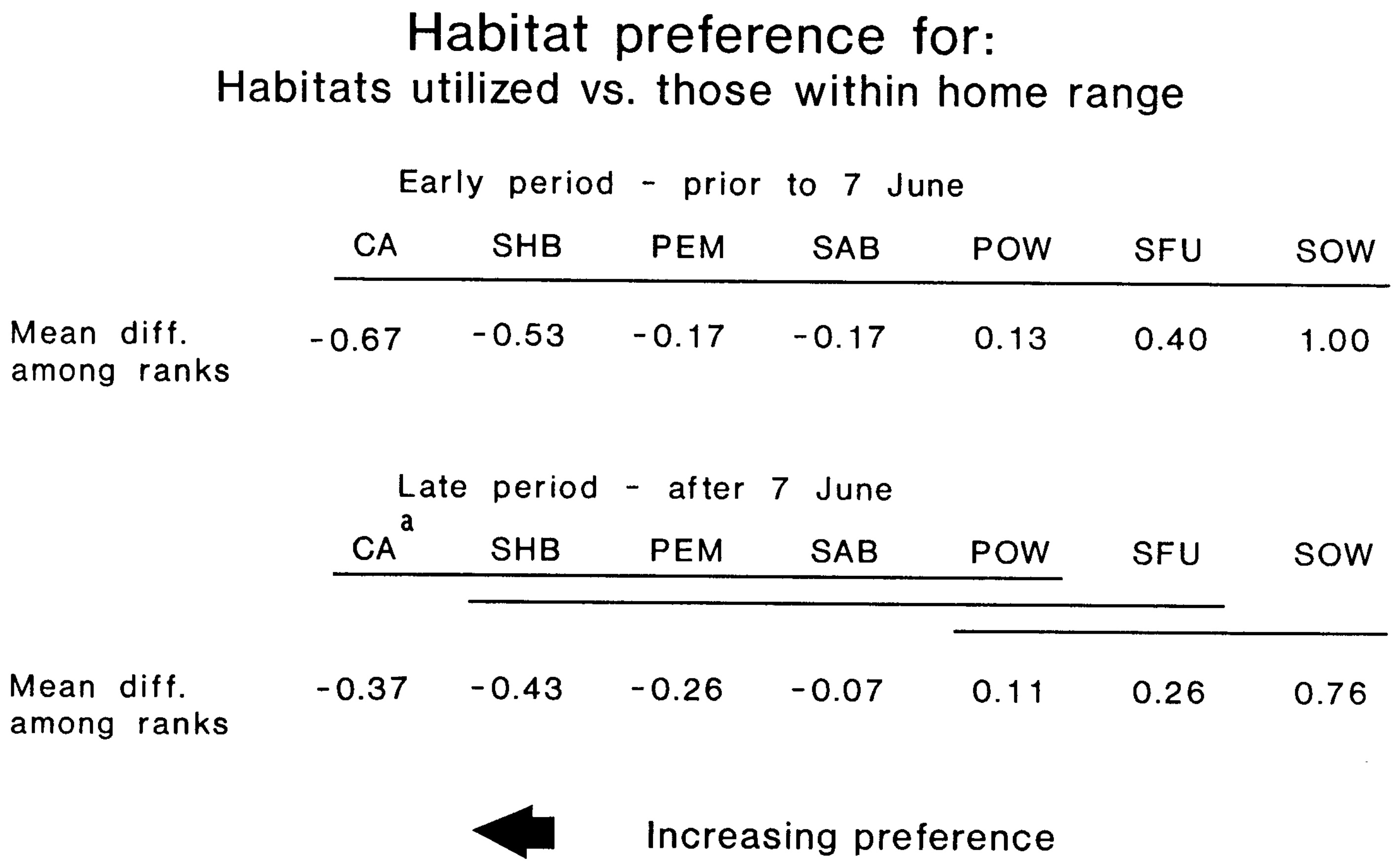


Fig. II.1. Preferences of habitat types within the home range of mallard broods compared to availability on Lower Klamath National Wildlife Refuge, California, 1989-90. Underlining indicates no significant difference (P < 0.05). SHB = Seasonal hardstem bulrush, SFU = Seasonal flooded upland, CA = Canals, SAB = Seasonal alkali bulrush, POW = Permanent open water, PEM = Permanent emergent marsh, and SOW = Seasonal open water.

ranges randomly or the power of the Johnson (1980) method was too low to detect selection. Most statistical tests of habitat use have low power (White and Garrott 1986).

During the late period, SHB was again the most preferred habitat type followed by CA and PEM marshes (Fig. II.2). The mean difference in ranks among habitat components were small compared to the mean difference in rank at the second order (Fig. II.1-II.2).



Habitat preference for:
Habitats utilized vs. those within home range

Early period - prior to 7 June

	CA	SHB	PEM	SAB	POW	SFU	SOW
Mean diff. among ranks	-0.67	-0.53	-0.17	-0.17	0.13	0.40	1.00

Late period - after 7 June

	CA[a]	SHB	PEM	SAB	POW	SFU	SOW
Mean diff. among ranks	-0.37	-0.43	-0.26	-0.07	0.11	0.26	0.76

[a] CA and SHB reversed in order to facilitate drawing lines of no difference.

Fig. II.2. Preference of habitat types utilized compared to those available within the home range for mallard broods from Lower Klamath National Wildlife Refuge, California, 1989-90. Underlining indicates no significant difference ($\underline{P} < 0.05$). SHB = Seasonal hardstem bulrush, SFU = Seasonal flooded upland, CA = Canals, SAB = Seasonal alkali bulrush, POW = Permanent open water, PEM = Permanent emergent marsh, and SOW = Seasonal open water.

DISCUSSION

Results from this study indicate that most habitat selection occurred at the second order; hens were selecting home ranges which contained a high proportion of preferred habitats (SHB, SFU). In the third order analysis, selection was weak.

In general, seasonally flooded habitats with a cover component were significantly preferred over permanent and open water habitats. Seasonally flooded marshes are known to support high populations of aquatic invertebrates (Swanson and Meyer 1973), an important food source for broods (Chura 1961, Sugden 1973) and hens during the breeding season (Swanson et al. 1985). Aquatic invertebrate populations are known to decline as permanence of flooding increases (Whitman 1976). Talent et al. (1982) determined that mallard broods tended to move to wetlands containing high concentrations of chironomid (midge) larvae. McKnight (1969) found that uplands flooded when new impoundments were created were heavily used by broods of several dabbling duck species including mallards. He speculated that high invertebrate numbers were the reason for this phenomenon.

Mallard broods are known to prefer dense cover during brood rearing (Talent et al. 1982). Preference for dense stands of whitetop rivergrass (Scolochloa festucacea) by mallard broods hampered the ability of Cowardin et al. (1985) to obtain visual observations of broods.

The movements of brood rearing hens from nests in or surrounded by permanent marshes to seasonal wetlands provided further evidence for the preference for seasonal habitats. Sayler and Willms (1988) found that mallard broods often bypassed deeper permanent marshes to reach initial rearing sites in seasonal marshes. McKnight (1969) reported that several species of dabbling and diving ducks including mallards nested extensively in permanent water areas, but soon after hatching left these areas to reach newly flooded impoundments.

Evidence from this study indicates a possible association between survival of ducklings and habitat conditions. In 1989, a greater proportion of broods originating in permanent water areas lost radio-marked ducklings compared to those hens nesting in or adjacent to seasonally flooded habitats. Unfortunately, it is difficult to determine whether the increased mortality was due to conditions present in permanent marshes, to the increased mobility of broods within this habitat type, or some other factor. McKnight (1969) felt that a preponderance of long-term permanently flooded marshes had reduced the brood production potential of a spring fed marsh in Utah.

The loss of radio-marked ducklings in 1990 from broods originating in permanent marshes may not have been different from broods originating in seasonal marshes because of the development of several seasonal wetlands adjacent to permanent marshes on Lower Klamath NWR in 1990. Broods moved into these new wetlands soon after hatching and remained relatively sedentary, and thus may have been less exposed to predators than broods in 1989.

Low survival rates of both ducklings and broods on the study area in 1988 (Chapter I) is further evidence that habitat conditions may influence survival. During 1988, water was removed from most seasonal marshes prior to the peak of the mallard hatch, leaving little seasonal habitat available for broods. Brood (survival of at least duckling to fledging) and duckling survival in 1988 were 19 and 18%, respectively, compared to 63 and 37% in 1989 and 62 and 34% in 1990, respectively (Chapter I). In 1989 and 1990, seasonal marshes contained water through most of the brood rearing season.

CONCLUSION

The preference for seasonally flooded habitats and the apparent effect of habitat on survival should be of concern to waterfowl managers. Wetland degradation tends to increase inversely with the permanence of flooding (Turner et al. 1987). The effect this pattern of wetland degradation may have on survival of ducklings or recruitment warrants further study.

CHAPTER III RECRUITMENT OF MALLARDS FROM LOWER KLAMATH NWR

INTRODUCTION

Mortality or survival rates of mallards (Anas platyrhynchos) have been extensively studied through large scale banding programs (Anderson 1975, Anderson and Burnham 1976, Trost 1987), and the use of radio-marked hens (Reinecke et al. 1987). In contrast, estimates of recruitment have received relatively little attention (Cowardin and Johnson 1979). Low recruitment rates are currently thought to pervade the prairies and may also occur in other important production areas (Bartonek et al. 1984).

The 2 major components of recruitment are hen success (a function of nest success and renesting rate) and duckling survival (Cowardin and Johnson 1979). While nesting ecology has been extensively studied (see Bellrose 1976 for accounts by species), few reliable estimates of duckling survival exist. This lack of reliable estimates makes determining recruitment difficult. Johnson et al. (1987) concluded that knowledge of duckling losses were vital to our understanding of mallard populations.

Estimates of the productivity of mallards are predominantly based on the continent wide population (Munroe and Kimball 1982, Reynolds 1987). Failure to derive estimates for specific geographic areas is a limitation of these studies (Martin et al. 1979). Recently, several important studies of recruitment from the prairie pothole region of North America have been conducted (Cowardin et al. 1985, Greenwood et al. 1987). Both studies concluded rates of recruitment were insufficient to maintain mallard populations, largely because of low nesting success.

Because a significant proportion of the mallard population breeds outside the prairie pothole region (Sparrowe and Patterson 1987), estimates of recruitment from these areas are needed. The Klamath Basin of southern Oregon and northern California is one of the major waterfowl production areas of the intermountain west (Jensen and Chattin 1964, Bellrose 1976). Nesting studies from this area (Miller and Collins 1954, Rienecker and Anderson 1960) have indicated high nest success and excellent nest densities, however, the lack of reliable estimates of duckling survival have prevented calculation of recruitment. The purpose of this study was to estimate recruitment of mallards from Lower Klamath National Wildlife Refuge (NWR) from information that was gathered while studying the ecology of mallard broods.

STUDY AREA

Data were collected from 1988 through 1990 on the Lower Klamath National Wildlife Refuge (NWR) located in Siskiyou county California approximately 25 km south of Klamath Falls, Oregon. The refuge encompasses approximately 19,500 ha of permanent and seasonally flooded wetlands, uplands, canals, and barley (*Hordeum vulgare*) fields. Water levels in seasonal wetland units are artificially manipulated to encourage the growth of desired food plants, encourage the proper interspersion of emergent hydrophytes, and maintain a high population of aquatic invertebrates. Because of the threat of avian botulism (*Clostridium botulinum*), water levels in permanent marshes are kept at stable levels.

METHODS

The breeding population of mallards was surveyed via aircraft by refuge biologists during May of 1988-90. East-west transects, 0.5 mi (804 m) apart, covering the entire refuge were flown at approximately 150 ft elevation (46 m) and the number of pairs and lone drakes 0.125 mi (201 m) on each side of the aircraft were recorded. Transects provided 50% coverage of the refuge, thus counts were multiplied by 2. Because a portion of mallards are not seen during aerial surveys (Martin et al. 1979), total counts were multiplied by a visibility factor of 3.55 (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1977:Table 8).

Searching for nests was conducted from early April through mid-June. Methods utilized included searches both with and without dogs, and with the use of a 50 ft (15.2 m) chain drag pulled by 2 all-terrain cycles (ATCs) (Higgins et al. 1969). I spent a majority of my time searching thick cover; a habitat preferred by nesting mallards (Lokemoen et al. 1990). Areas searched included emergent marshes, islands, uplands and levee banks. Approximately 2 hrs were spent searching each area, thus areas of high nest density contributed more nests to the sample than areas of low nest density. Each nest was visited 2 to 6 times. One-hundred-twelve, 111, and 175 mallard nests were located during 1988, 1989, and 1990 respectively.

I used the method of Mayfield (1961, 1975) as modified by Johnson (1979) to calculate nest success. One exposure day was tallied for each nest that survived for 24 hrs. Destroyed nests were assigned exposure days equal to 40% of the interval between the previous and the final nest visit (Johnson 1979). Daily survival rates (DSR) of nests were calculated as

$$DSR = 1 - F/ED \text{ where,}$$

F = number of nests that failed to hatch,

ED = Total exposure days for all nests.

Nest success (P) was calculated as

$$P = DSR^{35}.$$

The value of 35 was used because the mean number of days a mallard is exposed to nest destruction (laying through incubation) is 35 days (Klett et al. 1986).

Hens that did not return to the nest after the initial visit were assumed to have abandoned the nest due to disturbance and were excluded from analysis. A hatched nest was defined as having hatched at least 1 egg, and the mean number of ducklings at hatch was determined by subtracting the number of unhatched eggs from the clutch size of hatched nests.

Hen success (H), the proportion of hens successfully hatching a clutch, was calculated using the formula proposed by Cowardin and Johnson (1979);

$$H = Pe^{(1-P)^2} \text{ where,}$$

P = Nest success.

Survival of ducklings was estimated from a sample of radio-marked broods. Brood hens were captured on their nests late in incubation (18-20 days). Each hen was fitted with a 23 g radio transmitter using the harness described by Dwyer (1972). On the date of hatch, 1.9-2.1 g radio transmitters were affixed to 2 ducklings per brood using the method described by Mauser and Jarvis (1991). One-hundred-twenty-seven ducklings from 64 broods were marked during the study; 36 ducklings from 18 broods in 1988, 41 ducklings from 21 broods in 1989, and 50 ducklings from 25 broods in 1990. The Kaplan-Meier (1958) method was used to estimate survival of mallard ducklings from hatching to fledging. Because of unreliable transmitters in 1988, I was unable to estimate survival of ducklings beyond 10 days; however, results in 1989 and 1990 indicated loss of ducklings after 10 days was negligible. A more detailed description of this aspect of the study is presented in Chapter I.

An average annual survival rate for adult and yearling female mallards was obtained from banding data from the Klamath Basin, California, as reported by Rienecker (1990) for 1965-1980. Mean survival of adult and yearlings was 0.55 and 0.49, respectively.

Spring-summer (15 May - 15 August) survival rates (0.82 -0.84) were derived from Anderson (1975) for the continental mallard population. I used a value of 0.83 in calculations of recruitment.

Recruitment (R) was defined as the number of females fledged per adult female in the spring breeding population and was estimated using a modified version of the formula of Cowardin and Johnson (1979). I had a direct estimate of duckling survival, thus estimates of mean brood size and brood survival were not required. The formula I used was

$$R = HZS_d/2 \quad \text{where,}$$

Z = Mean brood size at hatch,

S_d = Survival rate of ducklings from hatch to fledging.

I used the value 2 assuming a 50:50 ratio of males to females at fledging.

To determine the change in population size (C), the equation of Cowardin and Johnson (1979) was used:

$$C = S(1 + DR/S_b) \quad \text{where,}$$

S = Annual survival of adult females,

D = Ratio of annual survival of yearlings and adults,

S_b = Summer survival rate of yearling and adult females (assumed to be equal).

The number of fledged young (FY) produced each year was estimated by the formula

$$FY = BHZS_d \quad \text{where,}$$

B = Number of breeding pairs.

RESULTS

Results demonstrate the variable nature of mallard production on Lower Klamath NWR. Estimates of the number of breeding pairs, nest success, mean brood size at hatch, duckling survival, and number of fledged young all varied markedly during the 3 years of the study (Table III.1). Estimates of recruitment and the proportional change in population size varied from 0.31 and 0.73 to 1.26 and 1.29, respectively (Table III.1).

Table III.1. Estimates of parameters used to calculate recruitment, change in population size, and number of fledged young for mallards breeding on Lower Klamath NWR, California, 1988-90.

	Year		
Parameter	1988	1989	1990
Breeding pairs	1,463	2,422	3,039
Nest success	0.254	0.688	0.388
Hen success	0.440	0.760	0.560
Mean brood size at hatch	7.90	8.96	8.67
Duckling survival	0.18[a]	0.37	0.34
Number fledging	915	6,102	5,017
Recruitment	0.31	1.26	0.83
Adult female survival (Rienecker 1990)	0.55	0.55	0.55
Yearling female survival (Rienecker 1990)	0.49	0.49	0.49
Summer survival (Anderson 1975)	0.83	0.83	0.83
Proportional change in population size	0.73	1.29	1.04

[a] Estimated survival for initial 10 days of life.

DISCUSSION

I assumed that the sample of radio-marked hens and nests were representative of the population and that radio transmitters did not adversely affect ducklings or brood hens. Gilmer et al. (1974) and Cowardin et al. (1985) found no evidence that transmitters affected radio-marked hens. Evaluation of the effects of radio transmitters on ducklings indicated negligible impacts (Chapter I). If transmitters did negatively affect ducklings, true survival rates would have been higher, resulting in increased estimates of recruitment.

I also assumed that the relationship used to calculate hen success was applicable to mallards breeding on Lower Klamath NWR. Cowardin and Johnson (1979) felt the equation was suitable for long term averages but in any given year climatic conditions or availability of food resources (Krapu et al. 1983) could cause a significant reduction in renesting rates. Climatic conditions differed between 1988 and 1989-1990. Several snowstorms in April and May of 1988 appeared to cause large scale abandonment of nests by laying hens and may have delayed nest initiation in other hens. In contrast, the spring of 1989 and 1990 were relatively warm with no periods of snow. The effect of these weather patterns on renesting rates among years is unknown.

The estimate of the number of fledged young among years may have been strongly influenced by the estimated breeding population. Aerial surveys are notoriously inaccurate (Caughley et al. 1976) and high variability often results even with identical aircraft, weather conditions, and observers (Stott and Olson 1972). In addition, the visibility correction factor of 3.55 derived from prairie habitats may not be applicable to Lower Klamath NWR, a relatively large contiguous marsh compared to the pothole landscape of the prairies.

The mean brood size at hatch may have been positively biased if predators removed eggs prior to hatching of the clutch. This would inflate the estimate of initial brood size and result in an over estimate of recruitment.

The spring-summer survival estimate I used for adult and yearling hens (0.83) may be an underestimate of the true survival rate. During the 3 years of the study, no radio-marked hens (_n_ = 77) were lost during the brood rearing or postbreeding period (to approximately 10 August). Unfortunately, hens were not under observation during the entire nesting period when survival of females is low (Sargeant et al. 1984), however, I believe losses of hens during nesting were small. Of 401 mallard nests located, I found evidence that hens were killed in only 3 instances. Of the major predators of nesting hens in the prairies (Sargeant et al 1973, 1984), red foxes (_Vulpes_ _fulva_) were absent and mink (_Mustella_ _vison_) were uncommon on Lower Klamath NWR (J. Hainline, Klamath Basin NWR, pers. commun.). Survival of hens during the molt, a period where survival rates are largely unknown, was also not determined. A higher summer survival rate would increase yearly survival, assuming no compensatory mechanisms, and increase the estimates of population change.

The variable nature of mallard production is not surprising. The mallard is adapted to surviving in a dynamic and unpredictable set of environmental conditions (Krapu et al. 1983) and is thought to be r-selected relative to other waterfowl species (Patterson 1979). The actual variability may have been greater than my calculations indicate. While I was able to obtain yearly estimates of nest success and duckling survival, I had to use constant survival rates for adults and yearlings. As a consequence, the only true variable in the equation for proportional change in population size was estimated recruitment. It is unlikely that annual survival of adult and yearling females was constant in 1988-90 as evidenced by the variation in survival rates within reference area 101 (northern California) of both age classes between 1975 and 1985 (Chu and Hestbeck 1989). Unless there was compensation between survival and recruitment, variable annual survival rates would have increased the variability of estimated proportionate changes in population size.

Other estimates of recruitment from specific geographic areas have demonstrated the dynamic nature of yearly recruitment rates. Greenwood et al. (1987) found that recruitment rates from 17 study areas in Alberta, Saskatchewan, and Manitoba ranged from 0.04 to 0.94 juveniles/adult, and average annual recruitment rates by year ranged from 0.23 to 0.60 for 1982 to 1985. They acknowledged that actual variation in recruitment rates may have been higher had they incorporated variation in duckling survival. Cowardin et al. (1985) determined a 4-year mean recruitment rate of 0.27 using a value of 4.9 young per fledged brood and 0.74 for brood survival. They determined that this recruitment rate would result in a population decline of 20% and concluded that the breeding population was being augmented by birds from other areas. Johnson et al. (1987) in simulations with a stochastic model found that varying the estimate of duckling survival ±50% resulted in an increase in recruitment of 67.5% or a decrease of 47.3%, respectively.

Continental mallard production rates, defined as the ratio of young to adults in the September population, for 1961-1975 ranged from 0.75 to 1.44 (Martin and Carney 1977). Reynolds (1987) determined continental production rates of 0.7 to 1.6 for the years 1961 to 1985. The incorporation of many geographic regions probably dampens the variability from smaller geographic areas.

Cowardin et al. (1985) determined that 15% nest success or 31% hen success were required on their North Dakota study area to achieve a constant population. However, results from Lower Klamath NWR indicate that these parameters may not be applicable to other areas. Despite the relatively high estimated nest (0.25) and hen success rate (0.44) in 1988, the recruitment rate of 0.31 resulted in a calculated decrease in the population of 27%, primarily due to low survival of ducklings (0.18). In my opinion, without reliable estimates of duckling survival, required rates of nest or hen success needed to maintain a population have little meaning.

The low estimate of duckling survival in 1988 (0.18) appeared to result from early drying of the seasonally flooded marshes (March to April), the preferred habitat for broods on Lower Klamath NWR (Chapter II). In addition, hatching of clutches was delayed in 1988 due to several periods of snow in April and May. This situation is analogous to Dzubin's (1969) discussion of "lethal brood areas" where hens are attracted to nest, but the lack of brood water results in high rates of mortality. In 1989 and 1990, water was removed from seasonal marshes in June, and survival of ducklings improved to 0.37 and 0.34, respectively. In the prairie region of Canada and the U.S., production rates (ratio of young to adults in September) are positively correlated with July pond numbers (Reynolds 1987). Apparently wetland conditions during the brood rearing period have a strong influence on annual recruitment.

The breeding population of mallards nearly doubled (Table III.1) on Lower Klamath NWR from 1988 to 1989, yet the estimate of population change indicated a decrease of 27%. Two explanations are possible; either a significant number of hens were pioneering or I severely under estimated recruitment. Drought conditions during the winter of 1988-89 in the Central Valley of California and eastern Oregon may have displaced breeding mallards to Lower Klamath NWR, an area having ample water supplies regardless of short-term hydrologic conditions. Both Cowardin et al. (1985) and Greenwood et al. (1987) similarly concluded that their respective study areas were being supplemented by birds from other areas.

CONCLUSION

Results from this study demonstrate the dynamic nature of recruitment in mallards; primarily due to variation in hen success (a function of nest success) and duckling survival. To adequately assess recruitment, reliable estimates of duckling survival are required.

Because the dynamic nature of mallard production makes accurate assessment of recruitment difficult, waterfowl managers should view estimates with caution. In particular, deterministic models utilizing average values of nest success, duckling survival or other variables are probably inadequate to accurately predict production in the mallard.

While long term declines in populations of mallards should be cause for concern, particularly due to permanently altered habitat, widely fluctuating short term population changes should be viewed as a natural attribute of the species. Accurate prediction of recruitment in an r-selected species such as the mallard, which exists in diverse, complex, and unpredictable environments, is probably not possible whether using deterministic or stochastic models. However, models promote an understanding of the factors governing mallard populations, thereby improving management capabilities and focusing research needs.

CHAPTER IV SURVIVAL, MOVEMENTS, AND HABITAT UTILIZATION OF POSTBREEDING MALLARD HENS

INTRODUCTION

The mallard (Anas platyrhynchos) is the most abundant, widely distributed (Bellrose 1976), and heavily harvested duck (Trost et al. 1987) in North America. Through the mid 1980's, fall flights of mallards reached record low levels (Reynolds 1987). While an extensive body of literature exists on the mallard, serious gaps in our knowledge remain, particularly concerning the postbreeding period. Postbreeding dispersal of waterfowl is a major reason for this paucity of information (Fredrickson and Drobney 1977).

Since the development of modern methods of band recovery analysis (Brownie et al. 1985), annual survival rates of mallards have been extensively studied (Anderson 1975, Trost 1987, Chu and Hestbeck 1989). Unfortunately, most of these studies have been unable to estimate survival rates from shorter time intervals (Blohm et al. 1987). Spring-summer survival of adult hens is especially important because hens killed during initial nest attempts are not available to renest. These after-second-year (ASY) hens tend to lay large clutches (Swanson et al. 1986) and experience high nesting success (Cowardin et al. 1985).

The few existing studies of spring-summer survival rates of hens were primarily conducted in mid-continent areas. Several of these studies subdivided spring-summer survival rates into shorter time intervals. Cowardin et al. (1985), Kirby and Cowardin (1986), and

Blohm et al. (1987) determined survival rates of 0.806 (April - September), 0.943 (18 June - 7 August), and 0.603 (spring-summer), respectively. Anderson (1975) concluded that the summer (15 May -15 August) survival of females for the continental population was 0.82-0.84.

While several authors have described activities during the postbreeding period (Hochbaum 1944, Oring 1964, Salomonsen 1968), little information exists concerning habitats utilized by postbreeding pre-flightless hens. Gilmer et al. (1977) reported that hens utilized mud bars and shorelines and, as the flightless period approached, moved to more permanent wetlands with emergent cover. Information pertaining to habitats utilized by incubating and postbreeding hens would be especially valuable to waterfowl managers having the ability to manipulate habitat.

I used radio telemetry to estimate survival rates and habitat use of brood rearing and postbreeding mallard hens. The Klamath Basin proved to be an ideal area to study postbreeding activities of mallard hens because wetland complexes were confined to inner valleys and old lake basins. In general, most hens remained within surveyed areas following the breeding season.

STUDY AREA

The study was centered on the Lower Klamath National Wildlife Refuge (NWR) located approximately 25 km south of Klamath Falls, Oregon, in Siskiyou County, California. Refuge habitats include 19,500 ha of seasonally and permanently flooded marshes, uplands, barley (*Hordeum vulgare*), and an extensive system of canals and ditches. The refuge is managed primarily for fall and spring migrant waterfowl but is also an important breeding area for waterfowl (Rienecker and Anderson 1960, Jensen and Chattin 1964, Bellrose 1976).

To locate hens leaving the study area, I periodically surveyed, via aircraft (Gilmer et al. 1981), major wetland areas between 122°15′ and 120°00′ west longitude and 43°00′ and 41°45′ north latitude. Major wetlands within the surveyed region included Abert Lake, Summer Lake Wildlife Area (WA), Sycan Marsh, Klamath Forest NWR, Goose Lake, Agency Lake, Upper Klamath NWR, Tulelake NWR, Clear Lake NWR, and Klamath WA (Fig. IV.1).

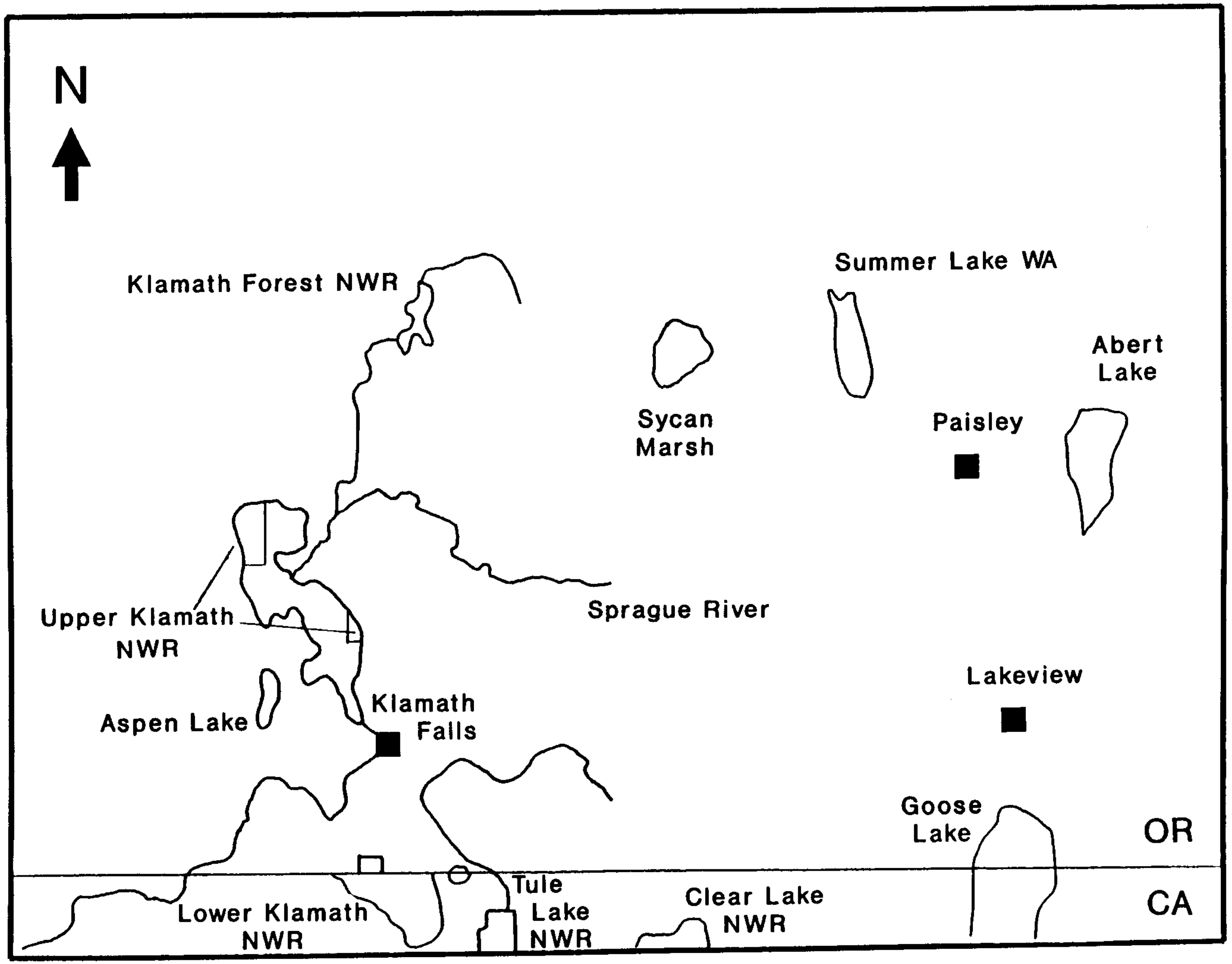


Fig. IV.1. Areas surveyed for radio-marked mallard hens from Lower Klamath NWR, California, 1988-90.

METHODS

Data were collected during 1988-90 as part of a study of the ecology of mallard broods on Lower Klamath NWR. All hens were captured on their nests at 18-20 days incubation using long handled dip nets or nest traps (Weller 1957). Each hen was fitted with a 23 g radio transmitter using the harness described by Dwyer (1972).

I monitored hens using a truck-mounted dual 5-element null detection system. Locations were calculated and stored using program XYLOG4 (Dodge and Steiner 1986) on a Zenith 180 laptop computer. Program XYLOG4 uses the method of Lenth (1981) to calculate a 95% confidence ellipse. Most hen locations were determined using 2 intersecting azimuths and birds were located from 1 to 6 times per week at >24 hr intervals. I felt that 24 hrs was a sufficient time interval to insure independence of transmitter locations.

Program XYLOG4 uses the standard deviation of error angle in determining a 95% confidence ellipse. I estimated the error angle by taking azimuths to transmitters at known distances and bearings (White and Garrott 1990:80). Once the standard deviation of the error angle was determined, I triangulated using 2 bearings to transmitters at known locations. The proportion of calculated confidence ellipses containing true locations was then subjectively determined. The true proportions could not be determined because the outside coordinates of the confidence ellipse are not given in program XYLOG4.

For postbreeding habitat use, hens were monitored from the time of brood loss until early to mid-August. Hens which were unsuccessful in hatching a clutch were considered to be in the postbreeding stage after 1 July if telemetry data indicated they were not tending a nest. Habitat utilization was compared among years and between successful and unsuccessful hens.

Data on habitats used by incubating hens covered the last 6-10 days of incubation. Monitoring began once the hen had returned to her nest after radio-marking. Only transmitter locations subjectively determined to be different than the nest coordinates were utilized. Distances traveled from the nest to wetland areas were calculated using an algorithm present in program HOMERANGE (Ackerman et al. 1990).

Habitats utilized by both postbreeding and incubating hens were categorized into 8 types. These habitats included emergent seasonal, mixed seasonal, and open seasonal marsh; emergent permanent and open permanent marsh; canals, and irrigated pasture or hay field.

Emergent seasonal and emergent permanent marshes were dominated by stands of hardstem (*Scirpus acutus*) bulrush with smaller quantities of cattail (*Typha latifolia*). Open seasonal and open permanent marshes lacked emergent vegetation but often contained beds of submergent plants. Mixed seasonal marsh typically contained a variety of plant types including smartweeds (*Polygonum sp.*), goosefoots (*Chenopodium sp.*), alkali bulrush (*S. maritimus*), and foxtail barley (*H. jubatum*). Canals were generally linear in conformation and ranged from devoid of vegetation to containing extensive growth of emergent wetland vegetation. Irrigated pasture existed solely on private land and consisted predominately of quackgrass (*Agropyron repens*). These areas were irrigated for short periods (<7 days) several times during the summer months. Water was removed from seasonal marshes from March - June and reflooding took place from September - November, while permanent wetlands remained flooded for the entire year.

Habitats of located hens were either recorded in the field at the time of location or later determined from habitat maps. Habitat maps were developed using a combination of color aerial photography and ground verification. Habitat preference (Johnson 1980, Thomas and Taylor 1990) was not determined because I did not have information on availability of habitats. Variability in the extent of seasonal marshes and irrigated pastures resulted in wide fluctuations in habitat availability, thereby making the collection of availability data near impossible.

The Mantel-Haenszel statistic (Anderson et al. 1980) and test was used to determine if the odds ratio (stratified by year) of the proportion of successful and unsuccessful hens which moved north of Klamath Falls or out of the surveyed area was equal to 1. The odds ratio (successful-to-unsuccessful) is defined as $(P_u/(1-P_u))$ divided by $(P_s/1-P_s))$, where P_u = the proportion of unsuccessful hens and P_s = the proportion of successful hens. Program STATXACT (Cytel Software Corp., Cambridge, Massachusetts) was used to calculate exact rather than asymptotic large sample p-values.

The Wilcoxon rank sum test was used to determine if the departure dates of successful and unsuccessful hens which moved north of Klamath Falls, or out of the surveyed area were different. Exact p-values were determined using program STATXACT (Cytel Software Corp., Cambridge, Massachusetts). Only data from 1990 was used in analysis because insufficient data existed from 1988-89. The date of departure was considered to be the date of last location south of Klamath Falls.

Survival rates of hens were determined from hatching of the brood through early to mid-August. Exposure days (survival of a hen for a 24 hr period) were totaled for all hens for each year. I considered an abrupt loss of radio signal from an otherwise trouble-free transmitter as an indication the hen had left the surveyed area. Erratic transmitter signals from a bird known to be alive followed by subsequent loss of the signal was considered radio failure. A bird was considered dead if the carcass was recovered or if physical evidence at the site of a recovered transmitter indicated mortality. Each bird was allowed a 7 day adjustment period after marking before I started counting exposure days.

RESULTS

Test of telemetry system

Tests of the telemetry system indicated that the standard deviation of error angle was <1° at 1 km distance from receiver to transmitter. Lee et al. (1985) felt that the standard deviation of error angle was the most appropriate measure of error. The extensive road system on the study area enabled me to locate hens at distances less than 1 km, resulting in 95% confidence ellipses of <1 ha. In addition, the flat terrain and lack of trees minimized signal bounce, a potential source of error (Hupp and Ratti 1983).

Survival of hens

Five-thousand-two-hundred-seventy-nine exposure days without the loss of a radio-marked hen were tallied for the 3 years of the study (Table IV.1). One bird was killed on the nest during the adjustment period by an unknown species of raptor and was, therefore, excluded from analysis. A second bird in 1990 was found dead during a botulism outbreak on 10 September, 20 days after we had ceased monitoring radio-marked hens. Three hens were shot during the fall in the Klamath Basin and 2 hens were shot near Gray Lodge Wildlife Area in the Sacramento Valley; all were direct recoveries. Two additional hens were found dead; 1 by a hunter near the town of Munser in eastern Washington (apparent nonhunting mortality) and the other an apparent road kill on the north end of the study area. Both of these mortalities occurred after the period of monitoring.

Table IV.1. Fate of mallard hens radio-marked on Lower Klamath NWR, California, 1988-90.

Year	N	Exposure days	Deaths	Number emigrating	Transmitter failure
1988[a]	26	1,516	0	2	1
1989[b]	19	1,419	0	0	3
1990[c]	32	2,344	0	2	3
Total	77	5,279	0	4	7

[a] Hens marked from 26 April to 30 June and monitored to 8 August.
[b] Hens marked from 2 May to 1 June and monitored to 8 August.
[c] Hens marked from 28 April to 21 June and monitored to 20 August.

Habitat utilization by postbreeding hens

A total of 1,521 locations from 70 radio-marked hens were used to determine habitat utilization of postbreeding hens (Table IV.2). Canals were the most frequently used habitat in 1988 while emergent permanent marsh and mixed seasonal marsh were the most frequently utilized habitat in 1989 and 1990, respectively. During 1988, 1989, and 1990, 30.8, 13.8, and 15.4% of all locations were on private lands, respectively. Of the total locations on private lands, 45% were in irrigated pasture with the remainder predominantly in canals.

The higher proportion of hens using private lands in 1988 may be related to a change in water management occurring on Lower Klamath NWR between 1988 and 1989-90. In 1988, water was removed from seasonally flooded and several permanent marshes during March and April. Thus, postbreeding hens had less habitat available during 1988 and may have been forced to use habitats on private land. In contrast, removal of water from seasonal marshes occurred during June in 1989 and 1990, with some of these areas retaining water into July. Thus, a larger wetland base was available for mallard hens during the final 2 years of the study. This change in water management may also explain the decreased use of canals and the increased use of mixed seasonal marshes in 1989 and 1990 compared to 1988.

Thirty-three percent of locations for successful hens were in seasonal marshes compared to 55% for unsuccessful hens (Table IV.3). The difference in these percentages is probably due to differences in availability of habitats. Most unsuccessful hens lost their broods early in the rearing season, prior to the removal of water from the

Table IV.2. Percentage of transmitter locations within each habitat category for postbreeding mallard hens on Lower Klamath NWR, California, 1988-90.

			Percent in each habitat type[a]						
Year	N	Number of locations	1	2	3	4	5	6	7
1988	25	357	9.4	11.1	11.7	33.6	13.3	8.6	11.7
1989	16	490	9.6	11.8	27.5	14.9	30.5	1.0	4.7
1990	29	674	7.7	17.2	29.1	10.7	21.7	4.3	9.3

[a] 1 = Emergent seasonal marsh
2 = Open seasonal marsh
3 = Mixed seasonal marsh
4 = Canals
5 = Emergent permanent marsh
6 = Open permanent marsh
7 = Irrigated pasture

Table IV.3. Proportional use of habitats by successful and unsuccessful postbreeding mallard hens from Lower Klamath NWR, 1988-90. (N = number of locations)

		Habitat type[a]						
	N	1	2	3	4	5	6	7
Suc.	313	12.8	5.4	15.0	29.8	26.8	3.5	6.7
Unsuc.	1,208	7.7	16.5	30.3	14.3	17.9	4.5	8.9

[a] 1 = Emergent seasonal marsh
2 = Open seasonal marsh
3 = Mixed seasonal marsh
4 = Canals
5 = Emergent permanent marsh
6 = Open Permanent marsh
7 = Irrigated pasture

seasonal marshes (1989 and 1990). In contrast, most seasonal marshes were dry when successful hens left their broods.

Movements

Unsuccessful hens did not immediately join molting drakes in the permanent marshes but tended to associate with small groups of other still-flighted mallards. I saw no evidence of hens molting, as evidenced by their mobility, until late July or early August, often over 2 months after losing their brood.

After fledging their broods, the 6 successful hens which moved to areas north of Klamath Falls or out of the surveyed area, remained on or near the study area an average of 28.5 days. In contrast, unsuccessful hens (14) remained an average of 42.4 days before moving north (Table IV.4). Using the Wilcoxon rank sum test, unsuccessful hens in 1990 moved north of Klamath Falls or out of the surveyed area significantly sooner ($\underline{P} = 0.016$) than successful hens (Table IV.4).

The Mantel-Haenszel test indicated no difference in odds ratios (successful-unsuccessful) among strata (years) ($\underline{P} = 0.655$) so data from 1988-90 were analyzed together. During the 3 years of study, of the 24 successful and 47 unsuccessful hens, 6 and 14 hens, respectively, made moves north of Klamath Falls or out of the surveyed area. No significant difference in these proportions were detected (estimated odds ratio = 0.964, $\underline{P} = 0.999$). Upper Klamath NWR appeared to be the most important area for hens moving north of Klamath Falls (Table IV.4).

One unsuccessful hen disappeared from the study area on 23 June and was shot on 20 November near Munser, Washington, indicating that

Table IV.4. Approximate number of days in residence and departure dates of successful and unsuccessful postbreeding mallard hens from Lower Klamath NWR to wetland areas north of Klamath Falls, Oregon, 1988-90.

		Successful hens		Unsuccessful hens			
Year	Hen	Date[a]	Days[b]	Date[a]	Days[c]	Destination	Dist.[d]
1988	348			26 July	29	Upper Klamath NWR	70
1988	020			9 Aug.	50	Upper Klamath NWR	70
1988	413			8 Aug.	69	Upper Klamath NWR	70
1988	436			26 July	49	Sprague River	60
1988	662			9 Aug.	55	Upper Klamath NWR	70
1988	320			20 July	28	Summer Lake WA	130
1988	541			20 July	37	Unknown	
1988	110			27 July	54	Unknown	
1989	042	27 July	7			Upper Klamath NWR	70
1989	101			6 July	45	Upper Klamath NWR	70
1989	461			13 July	60	Upper Klamath NWR	70
1990	602			3 July	10	Unknown	
1990	612			23 June	23	Unknown[e]	
1990	192			13 July	60	Upper Klamath NWR	70
1990	411			16 July	37	Klamath Forest NWR	100
1990	462	24 July	29			Aspen Lake	45
1990	532	20 Aug.	46			Upper Klamath NWR	70
1990	436	8 Aug.	25			Upper Klamath NWR	70
1990	513	20 Aug.	43			Upper Klamath NWR	70
1990	589	1 Aug.	21			Upper Klamath NWR	70
Mean		6 Aug.	28.5	20 July	42.4		73.4

[a] Date on which hen was last located on or near Lower Klamath NWR.

[b] Number of days between the fledging of the brood and movement to destinations north of Klamath Falls, Oregon.

[c] Number of days between loss of brood or nest and movement to destinations north of Klamath Falls, Oregon.

[d] Approximate linear distance (km) from Lower Klamath NWR to destination.

[e] Found dead near Okanogan River, eastern Washington 20 November 1990.

some hens may have moved north to molt. A few hens are known to accompany drakes on the northward molt migration (Salomonsen 1968).

Habitats utilized by incubating hens

Because habitat locations of incubating hens were used only if clearly different from the coordinates at the nest site, hens with nests located near the water's edge may have been able to move off the nest without my detecting the location. Thus, my estimate of mean distance to feeding sites may be positively biased.

One-hundred-nineteen locations from 47 radio-marked hens were used for analysis. Open seasonal and mixed seasonal marshes were the most frequently utilized habitats by incubating hens (Table IV.5). Radio-marked mallard hens moved a mean of 1,350 m (SE = 162, range = 56-10,943 m, median = 590 m) from nest sites to feeding locations.

Table IV.5. Habitat utilization (number of locations) by incubating female mallards on Lower Klamath NWR, California, 1988-90.

		Habitat type[a]						
Year	No. hens	1	2	3	4	5	6	7
1988	8	2	8	0	5	0	1	1
1989	18	4	20	13	5	3	0	3
1990	21	7	19	24	0	3	0	0
Total	47	13	47	37	10	6	1	4
Percent		11.0	39.8	31.4	8.5	5.1	0.8	3.4

[a] 1 = Emergent seasonal marsh
2 = Open seasonal marsh
3 = Mixed seasonal marsh
4 = Canals
5 = Emergent permanent marsh
6 = Open permanent marsh
7 = Irrigated pasture

DISCUSSION

Spring-summer survival information comes primarily from mid-continent North America. Cowardin et al. (1985) determined a July - September survival rate of 0.922. For their North Dakota study area, this interval corresponded to brood rearing through the molt. Kirby and Cowardin (1986) determined a survival rate of 0.943 for 18 June - 7 August (brood rearing to onset of the molt) in forested habitats in Minnesota. Blohm et al. (1987) estimated a spring-summer survival rate of 0.603 based on a banding study of female mallards in prairie Canada. Their estimate of survival included the period of nesting, a time of low survival of hens (Sargeant et al. 1984), and may not be comparable to results from this study where the period of nesting was not considered. Anderson's (1975) survival rate of 0.82 - 0.84 for the female segment of the continental mallard population was based on a time period of 15 May - 15 August, approximately the same period of time of this study. The high survival rate determined in this study may be due to the different predator communities in prairie habitats and on Lower Klamath NWR. For example, mink (Mustella vison) an important predator of brood rearing hens in the prairies (Sargeant et al. 1973, Cowardin et al. 1985) are rare on Lower Klamath NWR (J. Hainline, Klamath Basin NWR, pers. commun.).

The molt, an important period of survival for female mallards, was not considered in this study. Lower Klamath NWR appears to be an important molting area for locally breeding hens and hens breeding further south in the Central Valley of California (G. Yarris, California Waterfowl Association, pers. commun.). Unfortunately, the area is also an enzootic site for outbreaks of avian botulism (Clostridium botulinum). Outbreaks typically occur during August and September, the peak of molting for adult hens (Gilmer et al. 1977). As recently as 1987, an estimated 15,000 ducks were lost to botulism on Lower Klamath NWR (J. Hainline, Klamath Basin NWR, pers commun.). Hochbaum (1944) recognized the potential impact of this disease on molting hens on the Delta Marsh in Manitoba. The impact this disease may have on the molting population on Lower Klamath NWR is unknown.

Similar proportions of successful and unsuccessful hens moved north of Klamath Falls or out of the surveyed areas. This finding is in contrast to Gilmer et al. (1977) who found that while many successful hens remained, most unsuccessful hens breeding in Minnesota left their study area. My findings may be different for 2 reasons: 1.) unsuccessful hens may have moved north in late August or September, after I had ceased monitoring birds or 2.) unsuccessful hens may have remained on or near the study area because suitable food resources and molting areas were available.

Several factors make interpretation of habitat results difficult. Habitat availability varied widely during the spring and summer. Seasonal marshes comprised approximately 70% of the available habitat on Lower Klamath NWR during May in 1989-90 (removal of water in 1988 occurred in March - April), but typically declined to near zero by late July. The availability of irrigated pastures similarly fluctuated widely depending on the schedule of irrigations.

Another factor which confounds interpretation is that food or habitat preferences were probably changing over the time interval of the study. Hens utilized seasonally flooded marshes from May through mid-July, and switched to more permanently flooded habitats from late July through early August. This shift was probably due to 2 factors: the decline in the availability of seasonal marshes and the onset of the molt. Mallards are known to seek secluded permanent marshes during the molting period (Hochbaum 1944). Gilmer et al. (1977) determined that the molt for females started on or about 15 July.

Seasonally flooded habitats were the most frequently used by postbreeding hens prior to late July. These habitats are known to contain high populations of aquatic invertebrates (Swanson and Meyer 1973). Pederson and Pederson (1983) found that postlaying mallard hens on Lower Klamath NWR consumed 92% invertebrate foods, primarily chironomid larvae. They also reported that seasonal marshes in May contained twice the standing crop of invertebrates compared to permanent marshes. Thus, seasonal marshes, and their higher populations of aquatic invertebrates, may be important to molting or pre-molting females because growth of feathers requires a high dietary intake of protein, second only to that required for reproduction (Heitmeyer 1988).

CONCLUSION

Adult females are the most important component of the mallard population. They tend to lay larger clutches (Swanson et al. 1986) and are more successful nesters than first year nesting hens (Cowardin et al. 1985). Unfortunately, the postbreeding requirements of adult hens remains largely unknown. For proper management, knowledge pertaining to this stage of the life cycle is needed. Presently, we know little of the food or habitat preferences of postbreeding hens. Hens may use this time to obtain energy resources needed for molting and migration, energetically costly processes. In addition, survival rates of molting hens have been little studied. This may be especially important in the intermountain west where avian botulism remains a major concern.

CHAPTER V ATTACHING RADIO TRANSMITTERS TO 1-DAY OLD MALLARD DUCKLINGS[1]

INTRODUCTION

Miniaturization of electronic components has resulted in increasingly smaller transmitters. When coupled with appropriate batteries, these transmitters have sufficient detection range and life expectancy to be useful in studying small, highly mobile animals. However, attaching transmitters on small, active animals in a manner that does not adversely affect them is difficult. The problem of attachment is compounded when the animal is young and rapidly growing. Suturing methods used on passerine birds (Martin and Bider 1978) and adhesive attachment methods (Graber and Wunderle 1966, Bray and Corner 1972, Raim 1978) were ineffective in preliminary trials with penned ducklings. Neither method was reliable beyond 10-20 days. Sutures pulled out as ducklings grew and glued transmitters detached as down was replaced by feathers. In addition, use of 2-methyl-cyanoacrylate (super glue) to attach transmitters could result in histotoxicity and an inflammatory response (Woodward et al. 1965). Because ducklings grow rapidly, attachment methods using a harness are inappropriate.

I describe a method for attaching miniature transmitters to newly hatched mallard ducklings that allows for the growth and development of instrumented birds. The technique was developed for use on a study of the ecology of mallard broods on Lower Klamath National Wildlife Refuge

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[1] Originally published in the Journal of Wildlife Management 55(3):488-491.

(NWR), California. The technique was approved for use by the Animal Welfare Committee at the Northern Prairie Wildlife Research Center (USFWS), Jamestown, North Dakota.

METHODS

The radio transmitter I used (19 x 8 x 11 mm) weighed 1.9-2.1 g and had a life expectancy of 50-60 days (Fig. V.1). Extending from the rear of the transmitter was a 14-cm antenna made of 0.64-diameter nylon coated stainless steel wire. The transmitter consisted of an SM1 transmitter (AVM Instrument Co., Livermore, Calif.) coupled to an Eveready E312-E mercuric oxide battery (Union Carbide, Danbury, Conn.). Protruding 12 mm from the front of the transmitter and incorporated into the potting material (dental acrylic) was a length of 0.61-mm diameter stainless steel wire. The anterior end of the wire was formed into an anchor with 2 projecting prongs. The wire projected downward from the plane of the transmitter at approximately 15° and the 2 anchor prongs were bent slightly downward. Two sutures of dental floss were attached to the top front and back of the transmitter with cyanoacrylate (super) glue.

I attached transmitters to the back between the wings of 1-day-old ducklings (Fig. V.2). The site of attachment, sutures, and scalpel were sterilized with isopropyl alcohol prior to the procedure. A 3-4 mm incision was made in the skin perpendicular to the body axis and the stainless steel anchor was placed under the skin, 1 prong at a time. The sutures were then placed through the skin under the transmitter. I drew the ends of the sutures over the top of the transmitter where they were fastened with cyanoacrylate glue. This procedure eliminated the need for suture passageways, which add mass and bulk to the transmitter package. With experience, transmitters could be attached in about 5 minutes. The sutures hold the transmitter in place while the skin

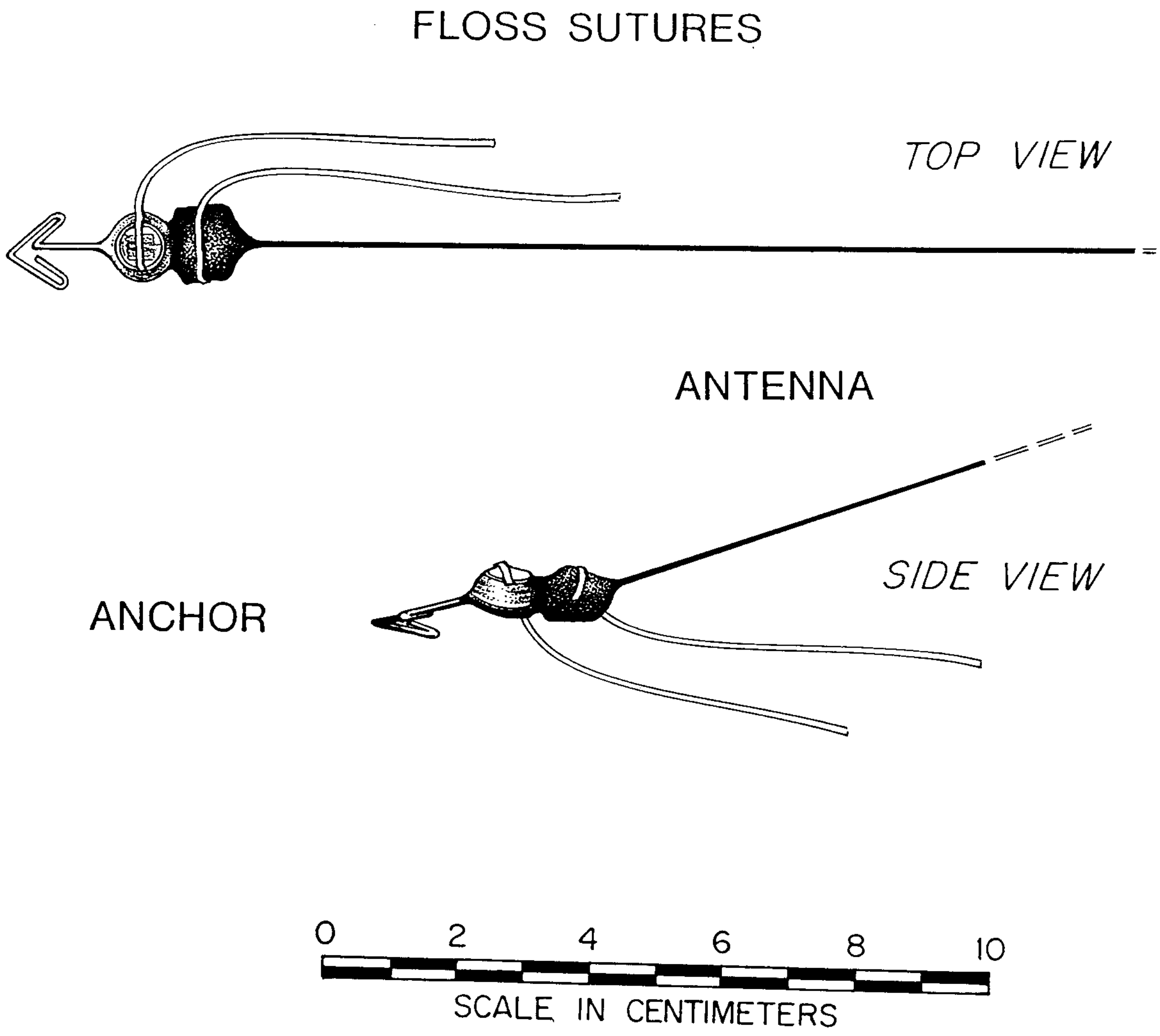

Fig. V.1. Radio transmitter used on 1-day-old mallard duckling.

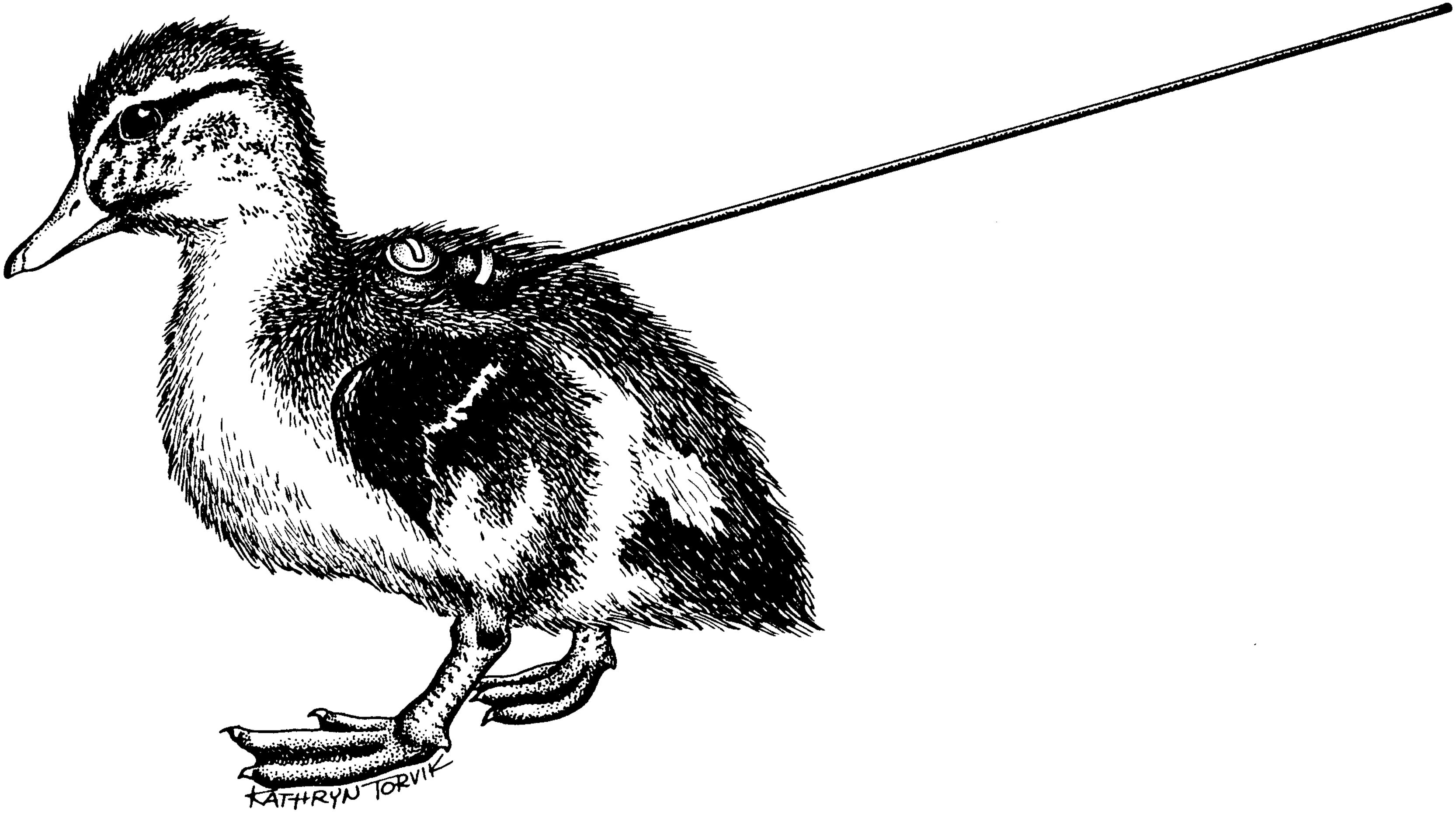

Fig. V.2. Proper placement of radio transmitter on a 1-day-old mallard duckling.

heals around the anchor in 2 - 3 days. After 10 - 20 days, the sutures often pull out and the anchor then provides a permanent means of attachment. Transmitters were shipped running from the factory via overnight mail, eliminating the added mass of a reed (magnetic on/off) switch. Because transmitters could not be switched off, I had to accurately predict hatching dates before ordering transmitters from the manufacturer. Transmitters weighed approximately 5-7% of initial duckling body mass.

Because birds are relatively insensitive to pain (AOU 1988), especially pain resulting from small incisions or punctures (Green 1979; Steiner and Davis 1981; T. Riebold, Oreg. State Univ., pers. commun.), I performed the procedure without a topical anesthetic. I felt the use of an anesthetic would increase handling time, which is the major cause of stress in birds (Gandal 1969). Because I was studying survival of ducklings, I sought to avoid adversly affecting survival probabilities. Although, I did not use a topical anesthetic for the attachment procedure, other researchers may feel its use appropriate. If an anesthetic is used, I recommend seeking the advice of a veterinary anesthesiologist.

Transmitters were affixed on the day of hatching, preferably while ducklings were still wet and lacked full mobility. Newly hatched ducklings were easy to handle and remained in the nest bowl both before and after attachment of transmitters. Older ducklings were active and difficult to hold while we attached transmitters, and they tended to flee from the nest causing the brood to scatter.

Pen-reared mallard ducklings

I developed the technique with 2 groups of pen-reared ducklings. The mechanics of the method was developed on the first group of birds (domestic mallard ducklings), and the effects on behavior and rates of growth were examined with a second group of wild strain mallard ducklings. Six ducklings received dummy transmitters, and two did not. Sample sizes were small due to limited rearing facilities. Dummy transmitters weighed 2.2-2.4 g, and all birds were fed a commercial chick starter ad libitum. Birds were weighed at 7-day intervals until 30 days of age and total mass gains for each group were recorded.

Wild mallard ducklings

During 1988-90, transmitters were attached to 127 wild ducklings from 64 broods. In all but 1 case 2 ducklings per brood were marked. To assess whether radios were adversely affecting wild ducklings, I counted marked and unmarked ducklings in broods. Chi-square analysis was used to test the hypothesis that the proportion of marked and unmarked ducklings lost from marked broods were not different. I observed birds opportunistically due to the secretive nature of mallard broods and the desire to avoid disturbance. Data were collected from broods <12 days of age because the ratio of transmitter to bird mass was highest and hence would most likely affect survival. Because the brood hen was also radio-marked, I used the signal from her transmitter to relocate broods. This eliminated potential bias caused by relocating broods with the signal from duckling transmitters.

RESULTS

Pen-reared mallard ducklings

Dummy transmitters >2.3 g appeared to impair the mobility of newly hatched ducklings. This impairment was evidenced by frequent stumbling and a general loss of balance. Dummy transmitters remained attached to ducklings in excess of 60 days when the trials were terminated. The body of the transmitter and often the antenna were preened under the feathers of the back as the ducklings grew older.

Total mass gain between the treatment and control birds was comparable. The 6 ducklings equipped with dummy transmitters gained an average of 698 g (range = 644-790 g) and the 2 control birds 659 and 695 g, respectively. (The small sample sizes preclude statistical analysis.)

Wild mallard ducklings

Nineteen of the 64 wild mallard broods were re-sighted when <12 days old, and 20 of the 38 marked ducklings and 59 of the 122 unmarked ducklings were lost. These proportions (0.53 and 0.48, respectively) were not significantly different ($\underline{X}^2 = 0.212$, 1 df, $\underline{P} = 0.64$). Although a 2 x 2 chi-square table lacks statistical power (White and Garrot 1990), the method appears to have little affect on survival of wild mallard ducklings.

Of 90 ducklings marked in 1989 and 1990 (transmitters in 1988 were unreliable beyond 14 days), at least 30 survived beyond 45 days of age. Radios remained attached to all 30 of these ducklings until transmitters failed.

Transmitter performance

Receiving range of transmitters was 0.4 - 1.6 km with a truck-mounted, 5-element, null detection system. Different receiving ranges probably resulted from differences in vegetation and topography. Maximum receiving range from aircraft was approximately 4.8 km with a 4-element, yagi antenna.

DISCUSSION

Determining survival rates of prefledging mallards has been difficult due to their secretive nature and the tendency for ducklings to inter-mix among broods as ducklings age. Survival of ducklings is a critical component of recruitment, yet only limited data exist (Cowardin and Johnson 1979, Cowardin et al. 1985). Recent studies of brood survival using radio-marked brood hens have reported a high incidence of total brood loss (Reed 1975, Ringelman and Longcore 1982, Talent et al. 1983), but the fate of individual ducklings could not be determined. By affixing transmitters on ducklings, researchers can determine the fate of individual ducklings. In addition, researchers can monitor broods without disturbing them. Attempting to obtain visual observations of broods often results in scattering ducklings, which could alter survival probabilities or movement patterns of ducklings and broods.

Radio-marking ducklings also aids in determining causes of mortality. For example, researchers can locate duckling remains or can identify predators that have ingested radio transmitters. Orthmeyer and Ball (1990) believed that the development of management strategies to increase duckling production was hindered by the lack of information on causes of duckling mortality. They also believed that this information could only be obtained through radio-marking individual ducklings. Talent et al. (1983) were able to establish the importance of mink as a predator of ducklings by releasing radio-marked, pen-reared ducklings on North Dakota wetlands. In my study of duckling survival on Lower Klamath NWR, functioning transmitters allowed me to relocate the remains of ducklings killed by predators and those lost to exposure. In addition, transmitters continued to operate when ingested by a California gull (Larus californicus) and a black crowned night heron (Nycticorax nycticorax), and when carried into the burrows of long-tailed weasels (Mustella frenata).

CONCLUSION

Potentially, use of the technique could be expanded to include small active animals of many species, especially young precocial birds. Larger animals which will not accept a harness might be another potential application; however, low mass transmitters should be used to minimize strain on the anchor. Although this method appears to be appropriate for use on mallards, its use on other species should be tested on pen-reared animals prior to use in field research.

CONCLUSION

While I learned much concerning the ecology of mallard broods, the study raised more questions than it answered. The following discussion is a combination of my impressions, management recommendations, and possible directions for future research.

Differences in survival rates among years appeared to result from changing habitat conditions. Seasonally flooded habitats were the preferred habitats of brood rearing hens. In 1988, a year of low survival, water was removed from seasonally flooded marshes prior to the peak of hatch. Thus, broods had little of this habitat available and mortality rates were high. In areas where wetland managers have water control, removal of water from seasonal wetlands should be delayed until the majority of broods are >2 weeks of age, a time when rates of mortality are declining. The exact timing of the drawdown will depend upon the phenology of the hatch. For example, in years when the mallard hatch is late due to climatic conditions or other factors, removal of water from wetlands should be delayed. To determine the exact time to remove water from marshes, a sample of nests should be located each year and the phenology of the hatch determined.

Preference for seasonally flooded marshes was evidenced by movement patterns of brood rearing hens. Brood hens which hatched their clutch in long-term permanently flooded habitats, moved their broods to seasonal habitats soon after hatching, and in 1990, lost a significantly greater proportion of radio-marked ducklings than broods from seasonal marshes. In addition, all relocation moves (>1,000 m) in the first week of life were made by broods originating in permanent wetlands. Because of this apparent increase in mortality with distance traveled, nesting cover planted for mallards should be near seasonal marshes, thus reducing distances broods must travel to reach rearing areas.

If the preference for seasonally flooded wetlands on an artificially manipulated area extends to unmanaged marshes, a major reason for concern exists. Unmanaged seasonally flooded wetlands are the most heavily impacted by drainage or other forms of wetland degradation. Further research is needed to determine the impact this practice may have on recruitment rates of mallards.

I believe brood hens departed long term permanent marshes because greater invertebrate densities were probably available in seasonally flooded wetlands. Wetland managers can increase the value of permanent marshes to broods through periodic drawdowns, thus stimulating aquatic productivity.

Rates of recruitment were found to vary widely during the study, demonstrating the dynamic nature of mallard production. It is doubtful that meaningful estimates of recruitment can be obtained without reliable estimates of the survival of ducklings. Unfortunately, obtaining estimates of survival is both time consuming and expensive. Currently, wetland managers and biologists have no reliable technique to routinely estimate this parameter. Methods of estimating survival based on data which can be readily obtained should be a research priority. Development of models incorporating brood survey information, and hydrologic and weather conditions is a potential first step.

Another area of potential research involves the brood ecology of the gadwall on Lower Klamath NWR. The gadwall is the most abundant breeding waterfowl species on the refuge and appears to use a different reproductive strategy than the mallard. Gadwalls nest later than mallards, thus reducing their reliance on residual vegetative cover for nesting. By nesting later, gadwalls also avoid the spring snowstorms of the Great Basin. In addition, gadwalls seem to readily accept permanently flooded habitats for brood rearing, a habitat generally shunned by mallard broods. The impact this reproductive strategy has on survival of gadwall ducklings is unknown.

Wetland management to reduce losses of waterfowl to avian botulism currently pervades many areas of the intermountain west. As a result, stable water levels are maintained in permanently flooded wetlands, thus reducing invertebrate productivity. While this practice may reduce losses of adult and juvenile mallards, it may also curtail production of mallards. This apparent trade-off between reduced losses of adults and juveniles to disease, and the potential for reduced production requires additional research.

The importance of adult hens to the population and the current paucity of information on survival rates, movements, and food and habitat requirements during the postbreeding period necessitate further research. Lower Klamath NWR proved an ideal area to study the activities and habitat use of postbreeding hens. Most radio-marked hens remained within the Klamath Basin, thus reducing the logistical constraints that typically plague studies of the postbreeding ecology of waterfowl.

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