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**SURVIVAL OF MALLARD BROODS ON BENTON LAKE NATIONAL WILDLIFE REFUGE
IN NORTH-CENTRAL MONTANA**

BY

DENNIS L. ORTHMEYER

B. S., NORTH DAKOTA STATE UNIVERSITY, 1976

Presented in partial fulfillment of the requirements

for the degree of

Masters of Science

University of Montana

1987

Approved by

Chairman, Board of Examiners

Dean, Graduate School

Date

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Wildlife Biology

**Survival of Mallard Broods on Benton Lake National Wildlife Refuge,
North-central Montana. (58 pp.)**

Director: I.J. Ball

Duckling survival was measured in broods of 31 radio-marked hen mallards (Anas platyrhynchos) on Benton Lake National Wildlife Refuge in north-central Montana during 1985 and 1986. Radio-marked hens were located 1 to 7 times daily. Observations of marked and unmarked broods supplied data on duckling survival. Overall survival for the 60 day pre-fledging period was 0.39, with 85% of the mortalities occurring within the first 18 days. Total brood loss occurred in 37% of all broods tracked, occurred within 24 days post-hatch, and accounted for 60% of all duckling losses. Broods that survived to fledging averaged 5.0 ducklings. Ducklings in broods that hatched early (before 10-June) had a 60-day survival probability of 0.44, significantly higher than in late broods (0.33). A significant correlation existed ($r = 0.46$, $P = 0.03$) between condition index of hens fledging broods and the number of ducklings they fledged. Condition index of hens declined as the season progressed. Mean brood size did not differ significantly between broods of radio-marked and unmarked hens.

Table of Contents

Abstract	ii
Table of Contents	iii
List of Figures	iv
List of Tables	v
ACKNOWLEDGMENTS	vi
INTRODUCTION	1
STUDY AREA	4
METHODS	8
RESULTS	14
Duckling Survival	15
Survival by age class	15
Total-Brood Loss	18
Survival in relation to nesting phenology	18
Survival in Relation to Condition	21
Duckling Survival in Relation to Movements	21
DISCUSSION	23
Appendix A. Habitat Use of Radio-marked mallard hens on Benton Lake National Wildlife Refuge.	31
Methods	31
RESULTS	34
Brood Use by Unit	34
Brood Use by Habitat Type Within Units.	34
Appendix B. Invertebrate availability in Units II, III, and IV-B on Benton Lake National Wildlife Refuge.	45
METHODS	45
RESULTS	47
LITERATURE CITED	55

List of Figures

Fig. 1. Benton Lake National Wildlife Refuge Impoundments and DNC Fields.	7
Fig. 2. Construction of radio transmitter and attachment to a hen mallard. Radio components consisted of an SM-1 transmitter, Hg 625 battery and antenna. (AVM INstrument Co. CA.)	10
Fig. 3. Composite survival curve of mallard ducklings in 1985 and 1986.	16
Fig. 4. Impact of egg and duckling loss on recruitment of a hypothetical population of 100 nesting mallard hens at Benton Lake NWR at nest success rates monitored in 1985 and 1986. Among hens losing their first nest, 50% were assumed to renested once. The category "eggs left" refers to infertile or addled eggs left in hatched nests; hence the apparent increase from 1985 to 1986 is related to the number of hatched nests, rather than to any change in hatchability.	30
Fig. 1. Habitat Use in Unit I 1985. Total number of brood days = 32.7.	36
Fig. 2. Habitat Use of Unit II 1985 and 1986. Total brood days 95.4 in 1985 and 33.6 in 1986.	37
Fig. 3. Habitat Use in Unit III 1986. Total brood days = 121.1.	38
Fig. 4. Habitat Use in Unit IV-A in 1985 and 1986. Total brood days in 1985 was 12.0 and 1986 3.0.	39
Fig. 5. Habitat Use in Unit IV-B 1986. Total brood days = 41.9.	40
Fig. 6. Habitat Use in Unit IV-C 1985 and 1986. Total brood days in 1985 = 13 and in 1986 = 109.9.	41
Fig. 7. Habitat Use in Unit V 1985 and 1986. Total brood days in 1985 = 20.0 and in 1986 = 54.3.	42
Fig. 8. Habitat Use in Unit VI 1985 and 1986. Total brood days in 1985 = 102.9 and in 1986 = 184.4.	43
Fig. 9. Habitat Use in Unit VII. (Main Canal) Total brood days 1986 = 63.3.	44
Fig. 1. Invertebrate Trap locations.	49
Fig. 2. Invertebrates collected Unit II North.	50
Fig. 3. Invertebrates collected Unit II South.	51
Fig. 4. Invertebrates collected Unit III.	52
Fig. 5. Invertebrates collected Unit IV-B.	53
Fig. 6. Invertebrate numbers and weights by day and location.	54

List of Tables

Table 1. Nest and brood fate for mallard hens marked at Benton Lake National Wildlife Refuge in 1985 and 1986.	14
Table 2. Comparison of brood sizes ($\bar{x} \pm SD$) between marked and unmarked mallard broods.	15
Table 3. Daily and interval survival in ducklings of radio-marked hen mallards at Benton Lake NWR. Z tests of daily survival rates between classes: I versus II = 9.27, P = 0.001; I versus III = 9.34, P 0.001; II versus III 0.58, P = 0.28.	17
Table 4. Comparison of reproductive parameters in early versus late broods. Cutoff hatch date for early versus late broods was 10-June.	19
Table 5. Survival rates by age class of mallard broods hatched early and late on Benton Lake NWR.	20
Table 6. Correlation between condition index and nest and brood variables for all hens, total brood loss hens and hens that fledged broods.	22
Table 7. Magnitude and timing of ducklings losses in mallard and black ducks.	27
Table 1. Marked hens and brood use of units in 1985 and 1986.	33
Table 1. Invertebrates collected in samples taken at Benton Lake NWR.	46
Table 2. Cumulative numbers and weights, mean water depth, and conductivity of Units II North, II South, III, and IV-B.	47

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INTRODUCTION

Populations of Mallards (Anas platyrhynchos) declined from an estimated 12.9 million breeding birds in 1958 to a record low of 5.4 million in 1985 (USFWS 1986). A similar decline occurred in several other species of dabbling ducks, including Northern Pintails (Anas acuta), which have dropped from 10.1 million in 1956 to 3.2 million in 1986. Collectively, population decline in upland nesting ducks is probably the most serious, and certainly the most widespread, problem facing game managers in North America. Excessive mortality, inadequate recruitment, or both could be responsible for the declines; the two explanations are not mutually exclusive biologically, although biologists and managers often seem to lose sight of this fact.

Proponents of the excessive mortality (overhunting) scenario maintain that hunting kill is largely additive to natural mortality, and that hunting mortality at levels occurring in recent years has caused the populations decline(s). Earlier studies seemed to support an additive mortality hypothesis (Hickey 1952, Geis 1963). However, recent studies based upon rigorous statistical evaluations of band recovery data generally support the hypothesis that hunting mortality at levels occurring over the last past several decades is largely compensatory (i.e. that natural mortality increased during the years of low hunting mortality so that overall annual mortality rates did not vary with increasing or decreasing hunting kill)(Anderson and Burnham 1976, Nichols et al. 1982, Nichols and Hines 1983, and Nichols et al. 1984). The results of these analyses vary somewhat between mallard age and sex classes, but overall they seem to provide little evidence supporting overhunting as the primary cause of population declines.

The inadequate recruitment school maintains that a deteriorating habitat base in conjunction with increasing predator populations (Sargeant et al. 1984) have caused recruitment rates to drop below levels necessary to offset overall mortality rates; consequently, populations have declined. Nest success is the most important variable in the recruitment equation (Cowardin et al. 1985). Bellrose (1976) summarized earlier studies of mallard nest success and found that nest success for 7,778 nests averaged 45.9%. In contrast, recent studies indicate nest success of 8.3% (Cowardin et al. 1985), 9.0% (Livezey 1981), and 6.6% (Johnson 1983). This comparison is not completely valid because the earlier studies reported apparent nest success rates, which were inherently liberal in comparison to rates adjusted according to a period of exposure (Mayfield 1961,1975). None-the-less, a major decline in nest success is still obvious. Nest success below 15% Mayfield is inadequate to offset existing mortality rates (Cowardin et al. 1985).

Brood survival, a second factor in recruitment, is poorly understood and most difficult factor to study, but is important in understanding and modeling populations. Obtaining precise counts of brood members is difficult because of the dense habitat preferred by mallards (Talent et al. 1982,1983). Ringelman and Longcore (1982) found a similar situation in black ducks (Anas rubripes).

Benton Lake National Wildlife Refuge has high densities of nesting mallards in association with relatively high nest success. These factors combined with the good access and visibility make it an excellent area in which to study brood survival. The objectives of this study were to document the following aspects of mallard brood survival at Benton Lake National Wildlife Refuge:

- 1) daily and overall survival rates of mallard ducklings,
- 2) duckling survival relative to age and seasonal chronology of hatch,
- 3) amount of total brood loss, and
- 4) effect of body condition of hens on survival of their ducklings.

STUDY AREA

Benton Lake National Wildlife Refuge (Fig. 1) is located largely in Cascade County, Montana, with small portions in both Teton and Choteau counties. It was withdrawn from the Public Domain on 21 November, 1929 by Executive Order Number 5228. The 4,953 ha refuge lies on the western edge of Northern Rolling High Plains and Brown Glaciated Plains subregions (USDA 1978), the Northern Great Plains spring wheat region. The Region is characterized by fertile soils and smooth topography interspersed with breaks and coulees along present and historic waterways. Major land use surrounding the refuge is dryland small grain farming. The major soil type of the refuge is the Pendroy-Marias type (USDA 1982), including Thebo, Pendroy, Marvan, and McKensie clays. Nearly 70% of the 35.6 cm annual precipitation occurs between April and September.

During the Wisconsin glaciation, the Kewatin ice sheet covered the entire area and deposited a layer of drift on the divides north of the Sun River and west to Belt creek. The ice sheet dammed the Missouri, Sun, and Smith rivers and formed the Great Falls glacial lake, of which Benton Lake is a remnant.

Slightly more than half of the 4,953 ha. refuge is made up of upland habitats. Short grass prairie covers 2,348 ha. and is dominated by western wheatgrass (Agropyron smithii) and green needlegrass (Stipa viridula). Dense nesting cover has been planted in seven fields totaling 251 ha. Species composition includes tall wheatgrass (Agropyron elongatum), intermediate wheatgrass (A. intermedium), Alfalfa (Medicago sativa), and yellow sweetclover (Melilotus officinalis).

Prior to 1964, the Refuge received water only from the Lake Creek drainage

and only during periods of peak runoff. With changes in surrounding land use and increasing irrigation runoff to the refuge gradually declined until the lake held water only sporadically during the 1950's. During the early 1960's dikes were constructed to divide the lake bed into impoundments. A ditch and pipeline were completed in 1964 allowing delivery of water from Muddy Creek, 22 km to the west. The water delivery system facilitated dependable water levels, but also complicated the management task because energy costs of pumping are high and because flows from Muddy Creek are primarily runoff from the Greenfield Irrigation project with an average pH of 8.0 and salinity levels of 600–800 micromhos/cm. Consequently, managers use local runoff to the extent allowed by annual snowfall.

An internal pumping system has been developed, allowing managers to control water levels within the seven individual units. The units are monitored and controlled for salinity and botulism, and habitats are manipulated to manage for invertebrates and emergent cover. Units I and II (Fig.1), the most northern units, are mandatory flow-through units; they contain 10 islands and dense stands of cattails (*Typha latifolia*). Units III,V,and VI are shallow-water management units that provide food, brood cover, nesting habitat, and loafing areas. Unit III is an open-water unit with one island (1.2 ha) for nesting and loafing. Unit V contains 66 islands for nesting and loafing. The shallow water of the unit provides excellent growing conditions for alkali bulrush (*Scirpus paludosus*). Unit VI has an excellent growth of alkali bulrush and contains 11 islands used for loafing and nesting. Unit IV is made up of three subimpoundments. Subimpoundment IV-A receives its only water from runoff flowing in from west of the Refuge. It has a narrow band of

cattail on the north edge but the unit usually dries up throughout the summer. Subimpoundment IV-B was constructed in 1985. The dike and 2 1.0 ha islands were constructed with funds provided by Ducks Unlimited. The subimpoundment received water for the first time in the spring of 1986. Subimpoundment IV-C serves as a sacrifice unit for reception of saline water from other units. It contains 15 islands and three areas of seasonal water which have stands of cattail, hardstem bulrush (Scirpus acutus), and alkali bulrush.

Fig. 1. Benton Lake National Wildlife Refuge Impoundments and DNC Fields.

**The six impoundments contain 2500 acres of water and the
seven fields contain 251 ha of Dense Nesting Cover.**

METHODS

Field work was conducted from 15 May to 15 August 1985 and 1 May to 25 August 1986. Nesting mallards were located by cable-chain drag (Higgins et al. 1969) or a 35m chain dragged between two all-terrain cycles.

Ongoing nest search operations at Benton Lake National Wildlife Refuge located nests in DNC fields and native prairie. Additional nest searches were made in dry cattail and alkali bulrush stands to locate nests specifically for this study. When the nest was first found, the eggs were counted and candled to determine stage of incubation (Weller 1956). Nests were marked with a small survey flag located 3 m from the nest to facilitate relocation and aid in the trapping effort. A small piece of survey ribbon or yarn was placed directly above the nest to mark the exact position of the nest bowl.

At approximately 20 days incubation, hens were captured with a dip net or bail-type nest trap (Schaiffer and Krapu 1978). The dip net,(2.7 m handle with a 91 X 76 cm hoop) was used during the initial trapping effort at the nest. As the observer approached the nest, the dip net was swung over the top of the nest bowl in an attempt to catch the hen as she flushed. If that was unsuccessful, a bail trap was placed. The trap was usually sprung between 1000 and 1500 hr the next day. Hens were banded with a standard USFWS aluminum legband, and marked with a nylon nasal marker (Lokemoen and Sharp 1985), and a 13 g radio transmitter (Fig. 2). Nests were designated as early if they hatched by 10-June and late if they hatched later than 10-June. Body weight, length of wing chord, time of capture, date, and number of eggs in the nest were recorded at the time of capture.

Transmitters were attached (Fig.2) by a modification of a method described by Martin and Bider (1978). The transmitters were sutured and glued to the hen. The transmitters were attached on the back, on top of the feathers between the wings. The area in which the sutures were sewn under the skin was washed with alcohol, along with the needle and suture material. The needle and suture material was passed subcutaneously 2 cm each side of the back bone. The sutures were drawn tight through the skin, pulling the transmitter tight to the skin on one side. Super glue was applied to the flat bottom of the transmitter and gently placed on top of the feathers between the wings. The suture lines were drawn tight, pulled up and over the transmitter, and then glued to the top of the transmitter. The hens were held for approximately 1 minute to allow the glue to set before release. Radio-marked hens were located two to three times daily. Triangulation points (MacDonald and Amalaner 1979, Springer 1979) were plotted on aerial photographs (20.2 cm = 0.6 km) and later transcribed to data sheets using the Universal Transverse Mercator system for coordinates. Aerial telemetry (Gilmer et al. 1981) was used when hens were not located for 5 days.

Observations of broods were attempted as often as possible with emphasis on sightings of marked broods every 5 to 8 days. Binoculars and 15 – 60 variable power spotting scopes aided observations. Observation of unmarked mallard broods provided supplemental information on brood size and age. During each observation the age class of ducklings (Gollop and Marshall 1954), number of brood members, location, nasal marker shape and color, and radio frequency were recorded.

Fig. 2. Construction of radio transmitter and attachment to a hen mallard. Radio components consisted of an SM-1 transmitter, Hg 625 battery and antenna. (AVM INstrument Co. CA.)

A nest was considered successful if at least one of the eggs hatched (Klett et al. 1986). Nests were visited within 6 hours after broods left to determine the number of eggs hatching and the number of ducklings leaving the nest site (initial brood size).

Age of captured hens was determined using the greater secondary covert weight and area of black-white region (Krapu et al. 1979). Ages were assigned according to the value of the discriminant score. If the value was negative the hen was considered to be an after-second-year hen and if the value was positive the hen was considered to be a second year hen (her first breeding season).

Condition index of nesting hens was determined by body weight of the hen divided by the length of the wing chord (Cowardin et al. 1985).

Duckling survival was calculated using a method originally developed by Mayfield (1961,1975) for calculating nest success rates and modified by Ringelman (1980) for application to duckling survival. The method weights survival by exposure days, and contains a midpoint assumption (i.e. ducklings alive on day 1 but dead or missing on day 10 are assumed to have survived 5 days). Thus, if a brood contained 8 ducklings on 1 June and 5 ducklings on 10 June, then 65 duckling-days (d-d) of exposure occurred (5 survived 10 days and 3 were assumed to have survived 5 days).

Daily mortality rates (DMR) were calculated as:

$$\text{DMR} = \text{N losses} / \text{d-d exposure}$$

$$\text{DMR} = 3 / 65$$

$$\text{DMR} = 0.0462$$

$$\text{Daily Survival Rate (DSR)} = 1 - \text{DMR} = 0.9538$$

Interval survival (IS) for the 10 day interval (i.e. the chance an individual duckling would survive the interval) was calculated as:

$$\text{IS} = (\text{DSR})^t$$

Where t = interval length. Hence:

$$\text{IS} = (0.9538)^{10} = 0.6234$$

If survival rates vary substantially over time or age, as they clearly do in duck broods, and if meaningful rates for the entire span are to be calculated, then data must be partitioned into intervals of reasonably stable rates (Johnson 1979, Bart and Robson 1982, Heisy and Fuller 1985). I chose to partition data according to mallard age classes as described by Gollop and Marshall (1954).

Class I (1 - 18 days)

Class II (19 - 45 days)

Class III (46 - 60 days)

Hence, if:

IS for Class I = 0.70

IS for Class II = 0.80

IS for Class III = 0.90

Then span (60 day) survival rate

$$= (0.70) \times (0.80) \times (0.90) = 0.50$$

Span survival of 0.50 is interpreted as a duckling having a 50% chance of surviving the 60 day brood rearing period. Standard estimators and confidence intervals were calculated using procedures described by Johnson (1979) and Heisey and Fuller (1985). Daily survival rates were compared between years, age-classes, and early and late broods by the z-test (Johnson 1979).

RESULTS

Forty-one mallard hens were trapped and radio instrumented during two field seasons (Table 1). Of 27 hens with known brood fates, 17 (63%) fledged young; and the proportion doing so did not change significantly between years ($\chi^2 = 0.0685$, $df=1$ $P = 0.79$).

Table 1. Nest and brood fate for mallard hens marked at Benton Lake National Wildlife Refuge in 1985 and 1986.

YEAR	HENS MARKED	----- NEST FATE ----- HATCHED DESTROYED ABN	----- BROOD FATE ----- FLEDGED TOTAL UNKNOWN
1985	16	11 2 3	6 (54%) 4 (36%) 1 (9%)
1986	25	20 2 3	11 (55%) 6 (30%) 3 (15%)
TOTAL	41	31 4 6	17 (54%) 10 (32%) 4 (12%)

ABN = Abandoned

Nest and brood variables were tested between years, at the 0.05 level of significance. Hen condition index, clutch size, initial brood size, and survival rates by years did not differ significantly between 1985 and 1986, (z and t-tests, $P > 0.05$), so years were combined in all analyses.

Marked and unmarked mean brood sizes did not differ within age classes of ducklings in 1986 (Table 2).

Table 2. Comparison of brood sizes ($\bar{x} \pm SD$) between marked and unmarked mallard broods.

----- Number of ducklings surviving -----			
	Class I	Class II	Class III
Marked	6.2 $\pm$ 2.7 _a	5.9 $\pm$ 2.0 _b	5.7 $\pm$ 2.1 _c
Unmarked	6.9 $\pm$ 2.5	6.6 $\pm$ 2.9	5.7 $\pm$ 1.7

a	t = 1.17, df = 73, P = 0.12		
b	t = 1.05, df = 63, P = 0.47		
c	t = 0.07, df = 25, P = 0.47		

Duckling Survival

Eighty-four ducklings (39%) survived through the 60 day period during the two year study (Fig. 3). Eighty-five percent (113/132) of the ducklings losses occurred in the first 18 days. Ducklings surviving the first 18 days had a 81% chance of surviving the next 42 days (Fig. 3).

Survival by age class

Sightings of marked broods numbered 237, generating 8,850 exposure days. Total duckling losses for the two year period were 130. Class I ducklings had a DSR of 0.9595 and a probability of surviving the 18 day interval of 0.4664 (Table 3). Class II ducklings had a DSR of 0.9955 and a probability of surviving the 27 day interval of 0.8887. Class III ducklings had a DSR of 0.9968 and a probability of surviving the 15 day interval of 0.9531. Overall probability of surviving 60 days to fledging was 0.3951.

Fig. 3. Composite survival curve of mallard ducklings in 1985 and 1986.

Table 3. Daily and interval survival in ducklings of radio-marked hen mallards at Benton Lake NWR. Z tests of daily survival rates between classes: I versus II = 9.27, P = 0.001; I versus III = 9.34, P 0.001; II versus III 0.58, P = 0.28.

YEAR	Daily Survival		Interval Survival	
	Rate	95% CI	Probability	95% CI
Class I (1 - 18 days)				
1985	0.9580	0.9458 0.9703	0.4627	0.3669 0.5817
1986	0.9588	0.9494 0.9680	0.4686	0.3930 0.5578
COMBINED	0.9585	0.9510 0.9659	0.4664	0.4045 0.5358
Class II (19 - 45 days)				
1985	0.9959	0.9918 0.9999	0.8946	0.8019 0.9975
1986	0.9955	0.9921 0.9988	0.8851	0.8084 0.9687
COMBINED	0.9956	0.9930 0.9982	0.8887	0.8288 0.9528
Class III (45 - 60 days)				
1985	0.9980	0.9941 1.0000	0.9705	0.9151 1.0000
1986	0.9960	0.9914 1.0000	0.9416	0.8996 1.0000
COMBINED	0.9968	0.9936 0.9999	0.9531	0.9093 0.9989

The DSR of ducklings differed significantly between Class I and Class II, but not Class II and III (Table 3).

Total-Brood Loss

Total-brood loss was experienced by 10 (37%) radio-marked hens for both years combined, four in 1985 and six in 1986. The last duckling was lost in four broods between days 1 and 7, in 5 brood between days 8 and 14, and in 1 brood at about day 25. Hens that experienced total-brood loss lost 78 ducklings during 1985 and 1986, or 60% of all losses and 69% of all losses in the first 18 days.

Survival in relation to nesting phenology

Early and late broods did not differ significantly with respect to hen condition index, clutch size, number of eggs hatched, or the apparent brood size at fledging (Table 4). In fact, apparent brood size at fledging was slightly higher in late broods than in early broods.

Table 4. Comparison of reproductive parameters in early versus late broods. Cutoff hatch date for early versus late broods was 10-June.

NEST CHRONOLOGY	HEN CONDITION		CLUTCH SIZE		EGGS HATCHED		BROOD SIZE AT FLEDGING $\bar{x}^a$
	N	INDEX	N	$\bar{x}$	N	$\bar{x}$	
EARLY	15	3.2 _b	138	9.2 _c	123	8.2 _d	4.9 _e
LATE	12	3.1	101	8.4	91	7.5	5.0

a Apparent brood size = number of ducklings in fledged broods divided by number of fledged broods.

b $t = -0.95$, $P = 0.35$

c $t = -0.14$, $P = 0.16$

d $t = 0.68$, $P = 0.50$

e $t = 0.09$, $P = 0.92$

Yet, Class I ducklings in early broods survived at a significantly higher daily rate than ducklings in late broods (Table 5). Also, overall (60 day) survival was significantly higher in early broods than late broods (0.44 versus 0.33, $z = 1.68$, $P = 0.04$)> The difference was a function of a higher incidence of total-brood loss in late broods (6 of 12 = 50%) than in early broods (4 of 15 = 27%).

Table 5. Survival rates by age class of mallard broods hatched early and late on Benton Lake NWR.

YEAR	<u>Daily Survival</u>		<u>Interval Survival</u>	
	Rate	95% CI	PROBABILITY	95% CI
Class I (1 - 18 days)				
EARLY	0.9657 _a	0.9570 0.9743	0.5337	0.4537 0.6268
LATE	0.9472	0.9339 0.9605	0.3768	0.2910 0.4846
Class II (19 - 45 days)				
EARLY	0.9958 _b	0.9927 0.9989	0.8921	0.8198 0.9707
LATE	0.9954	0.9908 0.9999	0.8822	0.7801 0.9972
Class III (45 - 60 days)				
EARLY	0.9950	0.9901 0.9999	0.9927	0.8618 0.9983
LATE	1.0000	1.0000 1.0000	1.0000	1.0000 1.0000

a z test (Class I early versus late) = 2.28, $P = 0.01$

b z test (Class II) early versus late) = 0.07, $P = 0.48$

Survival in Relation to Condition

Average condition index of hens for both years was 3.17 ± 0.22 . The average condition index of hens hatching nests before 10 June was 3.2 ± 0.19 compared to 3.1 ± 0.26 for hens hatching nests late. No significant difference was found in the condition index of hens hatching early or late. The average condition index of hens fledging broods was 3.16 ± 0.26 and those with total brood loss 3.17 ± 0.16 . No significant difference was found in the condition index of hens fledging broods and those experiencing total brood loss ($t = -0.13$ $P = 0.90$).

Linear correlations between condition indices of hens (all hens, hens that fledged broods, and those experiencing total-brood loss) versus number of ducklings hatching and number of ducklings fledging were tested (Table 6). The combined data demonstrated a positive correlation between the number of ducklings fledged and the condition index of the hens that fledged broods ($r = 0.46$ $P = 0.03$) (Table 6). No significant correlation was found between the condition index of hens and the number of ducklings hatching.

Duckling Survival in Relation to Movements

Initial distances moved from the nest to water ranged from 1 m to 258 m with an average of 91 ± 73.0 m. No significant linear correlation was shown between the initial distance moved and number of ducklings lost ($r = 0.53$ $P = 0.11$).

No overland moves after the initial move from the nest were documented in this study as reported by other researchers (Keith 1961, Dzubin and Gollop 1972,

Table 6. Correlation between condition index and nest and brood variables for all hens, total brood loss hens and hens that fledged broods.

	<u>HENS THAT FLEDGED BROODS</u>			<u>TOTAL BROOD LOSS HENS</u>			<u>ALL HENS</u>		
	N	r	P	N	r	P	N	r	P
Condition index vs Eggs hatched	17	0.17	0.24	10	0.54	0.05	27	0.25	0.10
Condition index vs Ducklings fledged	17	0.46	0.03	N A.			27	0.19	0.17

Ball et al. 1975, Talent et al. 1983). The study area is an impoundment type refuge, provides the only available water in the area, and the only overland moves made by broods was that of crossing 20 m wide dikes.

DISCUSSION

Ninety percent of the documented losses in mallard ducklings at Benton Lake occurred in the first 18 days post-hatch, and quite possibly losses were even more skewed to the first few days of life than could be detected by my re-observation schedule. Similar patterns of relatively high mortality in early life have been reported in mallards by Keith (1961), Dzubin and Gollop (1972), Ball et al. (1975), Talent et al. (1983), and in black ducks by Reed (1975). No causes of loss in marked mallard broods were documented in this study, although I observed ducklings of unmarked mallard hens and of other species being preyed upon by California gulls (Larus californicus), Ring-billed gulls (Larus delawarensis), and black crowned night herons (Nycticorax nycticorax). Predation has been suggested to be a major source of mortality on waterfowl broods (Eygenraam 1957) with the primary mammalian predator being mink (Mustela vison) in a study in North Dakota (Talent et al. 1983). Gull predation on ducklings has been documented by Dwernychuk and Boag (1972), with other mortality factors of ducklings being chilling and exposure (Nye 1964), and unknown factors during overland movements (Ball et al. 1975). A majority of the successful predation that I observed occurred when relatively young broods were crossing the open water and "moats" formed by borrow ditches along dikes and around islands. Limiting gull populations should help to control these losses, and I believe that several indirect methods also should be considered where practical.

- 1) Provide accessible, dry, vegetated, and loafing /brood sites that are directly surrounded by emergent vegetation. In construction of islands, consider a design where borrow material is taken from one side only (the side nearest to the dike or mainland) so that emergent vegetation can develop on the opposite side. Small haul islands or anchored logs in emergent cover may offer low cost options.
- 2) Promote development of shoreline and upland cover on dikes and islands.
- 3) Limit non-essential driving on dikes, and operation of airboat during the early brood period.

In the absence of direct evidence, only reasoned speculation is possible on the overall importance of various mortality sources. Losses to chilling and relatively inefficient predators like gulls should occur primarily in very young ducklings, as should losses associated with overland moves from nest to water. Losses to relatively efficient predators like mink and perhaps avian predators such as great horned owls (Bubo virginianus) should be spread more evenly over the rearing period. Given that relatively good observation conditions at Benton Lake, reasonable sample sizes of radio-marked brood hens, and intensive reobservation efforts resulted in essentially no convincing evidence on specific causes of mortality, I have serious doubts that causes can be discovered unless individual ducklings are radio-marked.

Declining condition of mallard hens during the nesting season was documented in North Dakota by Krapu (1981). The significant correlation between condition index of hens fledging broods and the number of ducklings fledged suggests that condition of the hen may in some way influences the her ability to fledge ducklings.

Daily survival rates, and thus interval survival, varied between age classes but not between years at Benton Lake. The class I interval survival of 0.46 was somewhat lower than the 0.52 reported by Cowardin and Johnson (1979) (Table 7). Ringelman and Longcore (1982) reported that survival of young black ducks for the first 24 days was 0.61 (versus 0.45 for the same time period in my study): they suspected that total-brood loss, and hence overall mortality during the interval, was underestimated. Duckling survival for the 42 day interval between days 19-60 (Class II - III) was 0.85, similar to the 0.82 figure developed by Cowardin and Johnson (1979) for mallards ducklings on the prairies. In contrast, Ringelman and Longcore (1982) estimated black duck duckling survival for the 36 day interval between days 25-60 at 0.70.

Overall duckling survival estimated in various published studies is relatively consistent, varying from 0.35 to 0.44 (Table 7). Further generalizations about duckling survival from published accounts are difficult, and the only hint of a possible pattern is that ducklings losses seem less confined to early life (i.e. relatively more losses occur in older age groups) in the more easterly, forested, study areas such as Minnesota and Maine.

Early broods did not differ in average brood size from late broods, although the 60 day survival of early broods (44%) was higher than survival of the late broods (33%). This indicates that loss occurring in the late hatch broods can be attributed to higher percentage of late hatch brood hens experienced total-brood loss. Declining physical condition of hens and a greater proportion of young hens hatching late may influence this higher loss. Ringelman and Longcore (1982) in

black duck ducklings and Grice and Rogers (1965) in wood duck ducklings reported higher survival in early hatched broods, while Dzubin and Gollop (1972) found a higher survival in late hatched broods.

Table 7. Magnitude and timing of ducklings losses in mallard and blackducks.

Source	Daily Survival Rate			Interval Survival			Overall Survival	Percent Total Brood Loss	Percent of Losses in first 2 weeks
MALLARDS									
Ball et al. 1975							0.44	23	70
Cowardin and Johnson 1979				0.52 ^{af}	0.92 ^b	0.89 ^c	0.43	30	
Talent et al. 1983							0.35	52	85
This Study	0.9585 ^a	0.9956 ^b	0.9968 ^c	0.46 ^a	0.89 ^b	0.95 ^c	0.39	37	90
This Study				0.45 ^d		0.87 ^e			
BLACK DUCKS									
Reed 1975							0.34	45	80
Ringelman and Longcore 1982	0.9794 ^d		0.9901 ^e	0.61 ^d		0.70 ^e	0.42	19	

a = 1 - 18 days

b = 19 - 45 days

c = 46 - 60 days

d = 1 - 24 days

e = 25 - 60 days

f = Calculated as Class I apparent duckling survival (0.74) X Brood survival to census (Z = 0.70) = 0.52

Total-brood loss occurred in 37% of all hens where brood fate could be determined. Ball et al. (1975) reported 23% in forested brood habitat and Talent et al. (1983) 52% total-brood loss in North Dakota. Total-brood loss in this study extended over a 25 day period, with a majority occurring within 18 days post-hatch. Talent et al. (1983) found a majority of total-brood loss occurred within 48 hours of the broods arrival on the wetland, while Duncan (1986) documented that 8 of 11 losses of entire broods occurred over 9 day period.

No losses of entire broods were documented on the initial move from the nest to water for any of my broods, as was also found by Talent et al. (1983). Duncan (1986) reported the loss of one brood from eight on the initial move from upland nest to water, and Dzubin and Gollop (1972) estimated that 48% of all broods hatched were lost on the initial move from nest to water.

Conditions for mallard brood rearing at Benton Lake appear to be excellent: nest-to-water distances are low, secondary overland moves by brood are rare, interspersed of emergent vegetation and open water is excellent, water levels are manipulated to increase invertebrate populations, and predator populations (except for gulls) are relatively low. Yet, 61% of all mallard ducklings hatched, and 32% of all mallard broods did not survive to fledging. Estimates of mallard production, particularly if total-brood loss is not addressed, may be unrealistically high.

Nest Success is a major determining factor for recruitment (Cowardin et al. 1985). At the relative low nest success rates commonly documented in recent studies recruitment rates are obviously driven primarily by nest success (or lack thereof). Drought conditions and heavy nest predation at Benton Lake in 1985

resulted in nest success of 18.6%, but improved water conditions and intensive predator removal occurred in 1986 and nest success increased to 71.0%. Duckling survival did not vary between years, and the relative of importance of nest success and duckling survival influencing recruitment could be compared (Fig. 4). At 18.6% nest success, eggs lost in the nest accounted for 82% of the potential recruits or roughly 8X the number of duckling losses. Conversely, at 71.0% nest success, duckling losses exceeded egg losses by 1.6X. Given the duckling survival regime at Benton Lake, losses of eggs and ducklings would be approximately equal at a nest success rate of 64%. Thus, management strategies to increase recruitment should focus first on obtaining or maintaining high nest success and secondarily on improving duckling survival.

Management techniques to improve nest success are well known (Balser et al. 1968, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980, and Klett and Duebbert 1984.) and seem to be practical and effective at Benton Lake. Efforts to improve duckling survival should focus on factors most critical during early life when most losses occur: adequate availability of invertebrate food resources; good interspersions of open water, emergent cover, and dry loafing/brooding sites; and reasonable security from gull predation.

18.6 % NEST SUCCESS

71.0 % NEST SUCCESS

Fig. 4. Impact of egg and duckling loss on recruitment of a hypothetical population of 100 nesting mallard hens at Benton Lake NWR at nest success rates monitored in 1985 and 1986. Among hens losing their first nest, 50% were assumed to re-nested once. The category "eggs left" refers to infertile or addled eggs left in hatched nests; hence the apparent increase from 1985 to 1986 is related to the number of hatched nests, rather than to any change in hatchability.

Appendix A

Habitat Use of Radio-marked mallard hens on Benton Lake National Wildlife Refuge.

Methods

Analyses of habitat selection by wildlife species typically focus on use of particular habitat types versus availability of those same types; the relationship between proportionate use and proportionate availability is evaluated to make inferences about habitat importance (Johnson 1980). The dynamic nature of marsh conditions at Benton Lake precluded such an analysis because fluctuating water levels and seasonal development of emergent vegetation made it impossible to establish a meaningful measure of availability. Consequently, I chose to present a relatively simple evaluation of what habitats were used by broods, irrespective of habitat availability. Intensity of brood use in each unit was estimated in brood days. A brood day represented one radio-marked brood hen in a unit for a 24 hr period as evidenced by 1 to 7 locations. If the hen used more than one Unit in a day, that brood day was apportioned in relation to the percentage of locations in each habitat type or unit (Ball et al. 1975). Broad habitat types could be used because most of the units were relatively homogeneous. For analysis of habitat use within units, habitat types were assigned to each radio location as follows:

UNKNOWN- Habitat type could not be determined because of darkness or inexact telemetry location.

OPEN EMERGENT- Plant species unidentified or mixed.

OPEN WATER- Brood was 5m from any emergent vegetation.

CATTAIL EDGE- Brood was within 2m of the edge of a cattail stand (inside or out).

CATTAIL- Brood was > 2m inside of a cattail stand.

BORROW DITCH- Brood was in the open water zone created by borrow areas along dikes or around islands.

BULRUSH- Alkali bulrush was the predominant species.

SHORELINE EMERGENT- Brood was < 15m from shoreline in emergent vegetation; plant species unidentified or mixed.

FLOODED UPLAND- Brood was in water with flooded upland vegetation. These sites were primarily dominated by foxtail (Hordeum jubatum).

UPLAND- Brood was in unflooded upland vegetation.

Table 1. Marked hens and brood use of units in 1985 and 1986.

UNIT	NUMBER OF MARKED HENS USING EACH UNIT		BROOD DAYS		PERCENT USE	
	1985	1986	1985	1986	1985	1986
I	5	0	32.7	0.0	11.8	0.0
II	7	6	95.4	33.6	34.5	5.8
III ^a	0	13	0.0	121.1	0.0	19.7
IV-A	2	1	12.0	3.5	4.3	0.5
IV-B ^b	0	11	0.0	41.9	0.0	6.8
IV-C	3	8	13.0	109.9	4.7	17.9
V ^c	5	10	20.0	54.3	7.2	8.8
VI	12	10	102.9	184.4	37.2	30.1
VII	0	9	0.0	63.3	0.0	10.0
TOTAL			276.0	613.0		

a Dry in 1985 because of construction activities.

b Constructed Nov. 1985, available to waterfowl spring 1986.

c Dry in mid-season 1985; available all of 1986.

RESULTS

Brood Use by Unit

Use of individual units by radio-marked broods varied substantially between years (Table 1). Unit VI received the most brood use in both 1985 and 1986. Unit II was the second in overall use in 1985, but most of its use in 1986 was transitory as hens shifted use to newly flooded Units III and IV-B. No radio-marked hens and broods used Unit VII (main canal) in 1985, but 9 did so in 1986 and the Unit supported 10% of all brood-days monitored. Pooling brood use of Units for both years is meaningless because of the major changes between years.

Brood Use by Habitat Type Within Units.

Cattail was the primary habitat used in Unit I receiving 64% of the use in 1985 (Fig.1). The unit received no use by radio-marked hens and broods in 1986. In Unit II, cattail received 59% and cattail edge 19% of the use in 1985, and cattail edge received 65% of the use in 1986 (Fig.2). The primary habitats used in unit III in 1986 were open emergents (41%) and shoreline emergents (31%) (Fig.3). On Unit IV-A, primary habitat used in 1985 was open emergents (45%) and alkali bulrush (20%), compared to 1986 when the primary habitat used was alkali bulrush (66%) (Fig. 4). Unit IV-A had only 2 hens and brood use the unit in 1985 and only 1 hen and brood in 1986. On Unit IV-B, which was first available in 1986, the primary habitat used was alkali bulrush (72%) (Fig.5). The primary habitat used on Unit IV-C was alkali bulrush in 1985 (64%) and 1986 (71%) (Fig.6). The primary habitat used on Unit V was open emergents in 1985 (72%) and 1986 (43%) (Fig.7). The primary

habitat used on Unit VI was alkali bulrush in 1985 (90%) and 1986 (78%) (Fig.8). In 1986, 9 radio-marked hens with broods used Unit VII (main canal), and they used cattail 79% of the time (Fig. 9).

Fig. 1. Habitat Use in Unit I 1985. Total number of brood days = 32.7.

Fig. 2. Habitat Use of Unit II 1985 and 1986. Total brood days 95.4 in 1985 and 33.6 in 1986.

Fig. 3. Habitat Use in Unit III 1986. Total brood days = 121.1.

Fig. 4. Habitat Use in Unit IV-A in 1985 and 1986. Total brood days in 1985 was 12.0 and 1986 3.0.

Fig. 5. Habitat Use in Unit IV-B 1986. Total brood days = 41.9.

Fig. 6. Habitat Use in Unit IV-C 1985 and 1986. Total brood days in 1985 = 13 and in 1986 = 109.9.

UNIT V habitat Use (%) 1985

UNIT V Habitat Use (%) 1986

Fig. 7. Habitat Use in Unit V 1985 and 1986. Total brood days in 1985 = 20.0 and in 1986 = 54.3.

Fig. 8. Habitat Use in Unit VI 1985 and 1986. Total brood days in 1985 = 102.9 and in 1986 = 184.4.

Fig. 9. Habitat Use in Unit VII. (Main Canal) Total brood days 1986 = 63.3.

Appendix B

**Invertebrate availability in Units II, III, and IV-B on
Benton Lake National Wildlife Refuge.**

METHODS

Funnel traps (Swanson 1978), were placed in units II North, II South, III, and IV-B (Fig. 1). Twenty traps were placed at random points along transect lines in each unit at approximately 13 day intervals. Traps were placed in a unit in the afternoon and removed 24 hr later. Contents of the traps were placed in storage jars containing 70% ETOH. At each trap location, five habitat variables were recorded:

- 1) the percentage of tall emergent within 5m diameter of the trap,
- 2) percentage of submerged vegetation within 2m diameter of the trap,
- 3) water depth,
- 4) nearest distance to tall emergent vegetation, and
- 5) conductivity (micro mhos / cm.).

Invertebrates were identified, sorted, and counted; dried at 50 °C for 48 hr, and weighed to the nearest .0001g.

Twenty-seven categories of invertebrates were identified (Table 1).

Table 1. Invertebrates collected in samples taken at Benton Lake NWR.

Scientific names	Common Names
GAMMARUS	FRESHWATER SCUDS
COLEOPTERA	
DYTISIDAE	PREDACEOUS DIVING BEETLES
STAPHYLINIDAE	ROVE BEETLES
CURCULIONIDAE	WEEVILS
HALIPLIDAE	CRAWLING WATER BEETLES
HYDROPHILIDAE	WATER SCAVENGER BEETLES
HEMIPTERA	
CORIXIDAE	WATER BOATMAN
NOTONECTIDAE	BACK SWIMMERS
GERIDAE	WATER STRIDERS
EPHEMEROPTERA	MAYFLY
BAETIDAE	"
CAENIDAE	"
ODONATA	
ZYGOPTERA	DAMSELFLIES
COENAGRIONIDAE	"
LESTIDAE	"
ANISOPTERA	DRAGONFLIES
AESHNIDAE	DARNERS
LIBELLULIDAE	SKIMMERS
DAPHNIA	WATER FLEAS
DIPTERA	
ADULT	FLYS
CHIRONOMIDAE	MIDGES
TRICHOPTERA	CADDISFLIES
LEPTOCERIDAE	
CHONCHESTRACA	CLAM SHRIMP
GASTROPODS	SNAILS
OSTACADA	SEED SHRIMP
HIRUDINEA	LEACH

RESULTS

Gammarus, Corixids, and Daphnia were the most numerous invertebrates collected; while Gammarus, Dytisids, and Corixids made up a majority of the invertebrate weight (Figs. 2-5).

Unit III had the lowest invertebrate diversity but had significantly higher cumulative number and weight of invertebrates than units II South, and Unit IV-B (t-tests, $P < 0.05$), and higher number ($P < 0.05$) but lower weight than invertebrates in unit II North (Table 2).

Table 2. Cumulative numbers and weights, mean water depth, and conductivity of Units II North, II South, III, and IV-B.

UNIT	NUMBER OF INVERTEBRATE TAXA	NUMBER OF INDIVIDUALS	CUMULATIVE WEIGHT (g)	MEAN WATER DEPTH (CM)	MEAN CONDUCTIVITY (MICRO MHOS/CM)
II-N	24	5060	29.7	20.6	2625
II-S	22	2304	12.2	25.6	2097
III ^a	16	34033	22.1	20.1	4697
IV-B	22	10500	12.2	19.4	2438

a a missed sample was assumed to have been equal to the lowest of the subsequent sample.

Unit II North had significantly higher cumulative invertebrate number, weight, water depth, and conductivity (t-tests, $P < 0.05$) than Unit II South. Unit IV-B had significantly higher total weights ($P < 0.05$) than Unit II North and Unit II South but not significantly higher numbers.

Number and weights of invertebrates varied widely between trapping days on

several Units (Fig. 6). Unit II North numbers increased primarily due to increased numbers of Corixids. An overall weight decline was influenced by the fewer adult Dytisids caught in the later samples. Unit II south showed a similar decrease in weight, but the numbers also declined. Unit III's numbers and weights increased dramatically between the two sampling periods: Corixids increased 730% between 14-July and 18-July. Unit IV-B showed a similar eruptive response in numbers but not in weight.

Unit III exhibited the highest brood use of sampled units (121 brood days in 1986) and the greatest total number of collected invertebrates. Causes of the high invertebrate populations could not be determined from this study, may involve reflooding in 1986 after being dry in 1985.

Fig. 1. Invertebrate Trap locations.

Invertebrate numbers Unit II North

Invertebrate weights Unit II North

Fig. 2. Invertebrates collected Unit II North.

Fig. 3. Invertebrates collected Unit II South.

Fig. 4. Invertebrates collected Unit III.

Fig. 5. Invertebrates collected Unit IV-B.

Fig. 6. Invertebrate numbers and weights by day and location.

LITERATURE CITED

- Anderson, D. R. and K.P. Burnham. 1976. Population ecology of the mallard. VI. The effect of exploitation on survival. U.S. Dep. Inter., Fish and Wildl. Serv. Resour. Publ. 128. 66pp.
- Ball, I.J., D.S. Gilmer, L.M. Cowardin, and J.H. Riechman. 1975. Survival of wood duck and mallard broods in north-central Minnesota. J. Wildl. Manage. 39:776-780.
- Balser, D.S., H.H. Dill, and H.K. Nelson. 1968. Effect of predator reduction on waterfowl nesting success. J. Wildl. Manage. 32:669-682.
- Bart, J., and D. S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. Ecology. 63:1078-1090.
- Bellrose, F.C. 1976. Ducks, Geese and Swans of North America. Stackpole Books, Harrisburg, Pa. 543pp.
- Cowardin, L.M., and D.H. Johnson. 1979. Mathematics and mallard management. J. Wildl. Manage. 43:18-35.
- _____, D.S. Gilmer, and C.W. Schaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monogr. No. 82. 37pp.
- Duebbert, H.F., and H.A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. J. Wildl. Manage. 38:257-265.
- _____, and J.T. Lokemoen. 1980. High duck nesting success in a predator-reduced environment. J. Wildl. Manage. 44:428-437.
- Duncan, D.C. 1986. Survival of dabbling duck broods on prairie impoundments in southeastern Alberta. Can. Field-Nat. 100:110-113.
- Dwernychuk, L.W. and D.A. Boag. 1972. Ducks nesting in association with gulls—an ecological trap? Can. J. Zool. 50:559-563.
- Dzubin, A., and J.B. Gollop. 1972. Aspects of mallard breeding ecology in Canada parkland and grassland. Pages 113-152. in Population ecology of migratory birds. U.S. Fish and Wildl. Serv. Res. Rep. No. 2.
- Eygenraam, J.A. 1957. The sex-ratio and the production of the mallard. (*Anas platyrhynchos*) L. Ardea 45:117-143.

- Geis, A.D. 1963. Role of hunting regulations in migratory bird management. Trans. North. Am. Wildl. and Nat. Resour. Conf. 28:164-171.
- Gilmer, D.S., I.J. Ball, L.M. Cowardin, and J. H. Riechman. 1974. Effects of radio packages on wild ducks. J. Wildl. Manage. 38:243-252.
- Gilmer, D.S., L.M. Cowardin, R.L. Duval, L.M. Mechlin, C.W. Shaiffer, and V.B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U.S. Fish and Wildl. Serv. Resour. Pub. 140. 19pp.
- Gollop J.B. and W.H. Marshall 1954. A guide for aging ducks broods in the field. Mississippi Flyway Council Tech. Sect. 14pp. mimeo.
- Grice. D. and J.P. Rogers. 1965. The wood duck in Massachusetts. Mass. Div. Fish and Game, Boston. 96pp.
- Heisey, D.M. and T.K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wildl. Manage. 49:668-674.
- Hickey, J.J. 1952. Survival studies of banded birds. U.S. Fish and Wildl. Serv., Spec. Sci. Rep. Wildl. 15. 177pp.
- Higgins, K.F., L.M.Kirsch, and I.J. Ball, Jr. 1969. A cable-chain device for locating duck nests. J.Wildl. Manage. 33:1009-1011.
- Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.
- _____. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.
- Johnson, M. 1984. A report presented at the joint meeting of Mississippi and Central Flyway Technical Committee. Wichita Kansas. Mimeo. 17pp.
- Keith, L.B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Monogr. 6. 88pp.
- Klett, A.T., and H.F. Duebbert. 1984. Use of seeded native grass as nesting cover by ducks. Wildl. Soc. Bull. 12:134-138.
- Krapu, G.L. 1981. The role of nutrient reserves in mallard reproduction. Auk 98: 29-38.
- Krapu, G.L., D.H. Johnson, and C.W. Dane. 1979. Age determination of mallards J.Wildl. Manage. 43:384-383.

- Livezey, B.C. 1981. Duck nesting in retired croplands at Horicon National Wildlife Refuge, Wisconsin. *J. Wildl. Manage.* 45:27-37.
- Lokemoen, J.T. and D.E. Sharp 1985. Assessment of nasal marker materials and designs used on dabbling ducks. *Wildl. Soc. Bull.* 13:53-56.
- MacDonald, P.W. and C.J. Amlaner. 1979. A practical guide to radio tracking. pages 143-159 *in* C.J. Amlaner and P.W. MacDonald, eds., *A handbook of biotelemetry and radio-tracking*. Pergamon Press, Oxford England.
- Martin, M.L. and J.R. Bider. 1978. A transmitter attachment for blackbirds. *J. Wildl. Manage.* 42:683-685.
- Mayfield, H. 1961. Nesting success calculated from exposure. *Wilson Bull.* 73:255-291.
- _____. 1975. Suggestions for calculating nest success. *Wilson Bull.* 87:456-466.
- Nichols, J.D., R.S. Pospahala, and J.E. Hines. 1982. Breeding ground habitat conditions and the survival of mallards. *J. Wildl. Manage.* 46:406-416.
- _____ and J. E. Hines. 1983. The relationship between harvest and survival rates of mallards: A straightforward approach with partitioned data sets. *J. Wildl. Manage.* 47:234-348.
- _____, M.J. Conroy, D.R. Anderson and K.P. Burnham. 1984. Compensatory mortality in waterfowl populations: A review of the evidence and implications for research and management. *Trans. North. Am. Wildl. and Nat. Resour. Conf.* 49:535-554.
- Nye, P.A. 1964. Heat loss in wet ducklings and chicks. *Ibis* 106:189-197.
- Reed, A. 1970. The breeding ecology of the black duck in the St. Lawrence estuary. D.Sc. Thesis. Univ. Laval. Quebec. 175pp.
- Ringelman, J.K. 1980. The breeding ecology of the black duck in south-central Maine. PhD. Thesis Univ. of Maine, Orono. 89pp.
- _____, and J.R. Longcore. 1982. Survival of juvenile black ducks during brood rearing. *J. Wildl. Manage.* 46:622-628.
- Sargeant, A.B., S.H. Allen, and R.T. Eberhardt. 1984. Red Fox predation on breeding ducks in midcontinent North America. *Wildl. Monogr.* 89. 41pp.
- Schaiffer, C.W., and G.L. Krapu. 1978. A remote-controlled system for capturing nesting waterfowl. *J. Wildl. Manage.* 42:668-669.

- Springer, J.T. 1979. Some sources of bias and sampling error in radio triangulation. *J Wildl. Manage.* 43:926-935.
- Talent, L.G., G.L.Krapu, and R.L. Jarvis. 1982. Habitat use by mallard broods in south-central North Dakota. *J. Wildl. Manage.* 46:629-635.
- _____, _____, and _____. 1983. Survival of mallard broods in south-central North Dakota. *Condor* 85:74-78.
- U.S.D.A.-S.C.S. 1978. Land resource regions and major land resource areas of the United States. U.S. Dept. Agric., Soil Conservation serv., Washington D.C. Agricultural Handbook 296. 82pp.
- U.S.D.A.-S.C.S. 1982. Soil survey of Cascade County area, MT. U.S. Dept. Agric., Soil Conservation Serv., Washington D.C.
- U.S.F.W.S. 1986. Status of waterfowl and fall flight forecast. U.S. Fish and Wildl. Serv. and Canadian Wildl. Serv. 38pp.
- Weller, M.W. 1956. A simple field candler for waterfowl eggs. *J. Wildl. Manage.* 20:111-113.