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Mallard Brood Movements in the Canadian Prairie Parklands

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ABSTRACT -- We radiotracked 308 mallard (*Anas platyrhynchos*) broods from hatching until 30 days of age on 15 study areas located throughout the Canadian Prairie Parklands to examine patterns of variation in movement frequency and distance. Broods moved an average of 350 m from nests to first wetlands (SD = 390), with 94% of broods moving less than 1 km. After leaving the nest, broods had a 23% probability of moving to a new wetland each day, but movement probability was a complex function of study area, hatch date, and ducking age, with younger and earlier-hatched broods exhibiting greater movement rates than older and later-hatched broods. Later-hatched broods moved farther than earlier-hatched broods and movement distance also varied among study areas. Local wetland characteristics explained some of the among-site variation in movement rates and distances, with movement probability being most strongly correlated with average size of semipermanent wetlands and movement distance being most strongly correlated with total acreage of seasonal wetlands. After 30 days, broods were located an average of 760 m (SD = 610) from their nests, with 95% of all surviving broods located less than 2 km from their nests. Our data illustrated the need for suitable brood-rearing wetlands within a reasonable distance (e.g., < 0.5 km) of waterfowl nesting cover.

Key words: *Anas platyrhynchos*, brood movements, Canadian Prairie Parklands, mallards.

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Mallard (*Anas platyrhynchos*) broods frequently move to new wetlands (Rotella and Ratti 1992a, Raven 2004), presumably because wetlands that they currently occupy do not meet their needs in terms of food resources or protective cover. Longer moves increase the probability of encountering a better quality wetland, but are energetically more costly and presumably increase the risk of predation or separation while traveling overland (Ball et al. 1975, Rotella and Ratti 1992a; but see Dzus and Clark 1997). If movement distance represents a tradeoff between costs of overland travel versus benefits of an increased choice set of potentially higher quality wetlands, then movement distance should vary with factors that alter the dynamics of this tradeoff, such as duckling age, date, or local wetland density.

Duckling age and date are known to affect other attributes of brood ecology, such as survival. The majority of duckling mortality occurs during the first two weeks after hatching (Ball et al. 1975, Orthmeyer and Ball 1990, Rotella and Ratti 1992a), concurrent with a period of extensive interwetland movements. As ducklings grow older and their locomotory skills improve, they should be better equipped to make longer and more frequent overland movements. Several studies have found that mallard broods hatched early in the season have a greater chance of survival than late-hatched broods (Orthmeyer and Ball 1990, Rotella and Ratti 1992a, Krapu et al. 2000; but see Mauser et al. 1994). This might occur because late-hatched broods have to move farther or more frequently because wetlands are more likely to become dry later in the season.

Regional distribution or quality of wetlands might also influence the frequency and distance of brood movements (Rotella and Ratti 1992b). Wetland availability can be low because the local landscape has relatively few wetland basins, but it can be further reduced by local drought conditions, during which many otherwise suitable wetlands dry up and become unacceptable as brood habitat. Local moisture levels are often indexed as the percentage of seasonal or semipermanent wetlands holding water, and these indices have been shown to affect survival and habitat selection of mallard broods (Rotella and Ratti 1992a, Krapu et al. 2000, Raven 2004), so it is reasonable to suspect that movement patterns might also be affected.

As part of a companion study to better understand habitat use by the mallard during brood rearing (Raven 2004), we examined the movement patterns of radiomarked broods in a variety of habitat conditions throughout the Canadian Prairie Parklands. Our objectives were to document the frequency and distance of interwetland movements in relation to brood age, hatch date, and local wetland conditions.

STUDY AREAS

We used data from 15 typically 65 km² study sites sampled from 1993 through 1997 as part of a large-scale investigation of the efficacy of waterfowl management efforts in the Canadian Prairie Parklands in Alberta (AB), Manitoba (MB), and Saskatchewan (SK) (Paquette et al. 1997). Our sample included two sites in 1993 (Punnichy, SK; and Hamiota, MB), three sites each in 1994 (Erskine, AB; Davis, SK; and Belmont, MB), 1995 (Shoal Lake; MB, Kutawa, SK; and Camp Lake, AB), and 1996 (Pine Lake, AB; Parkside, SK; and Baldur, MB), and four sites in 1997 (Willowbrook SK; Mixburn, AB; Elnora, AB; and Allan Hills West, SK) (Fig. 1).

METHODS

At each study site approximately 135 pre-laying female mallards were decoy-trapped and radiomarked with 22 g intra-abdominal implants (see Paquette et al. 1997 for additional details). At five of our study sites from one-fourth to one-half of the decoy-trapped individuals were radiomarked with 8 g anchored-backpack transmitters (Mauser and Jarvis 1991). Any decoy-trapped female that hatched a nest was eligible to become part of our brood movements study. We augmented



Figure 1. Locations of the 15 study areas used to evaluate mallard brood movements in the Canadian Prairie Parklands, 1993 through 1997.

this sample of decoy-trapped birds with a sample of nesting hens that were trapped at approximately 20 days of incubation by using mist nets (Bacon and Evrard 1989), purse traps (modified from Coulter 1958), automatic nest traps (Weller 1957), or walk-in traps (Dietz 1994). All nest-trapped hens were fitted with 8 g anchored-backpack transmitters. Although the two different transmitter types (implants vs. anchored-backpacks) appeared to cause subtle differences in nesting effort (Paquette et al. 1997), we have not documented any differences in brood-rearing behavior. Our capture and marking procedures were approved by the University of Saskatchewan's Protocol Review Committee on Animal Care and Supply (protocol # 920007).

Each brood hen was radiotracked once daily, unless a movement occurred between wetlands, in which case we collected a second location to verify that the brood also had moved. Telemetry locations were collected by using a truck-mounted null array system (Paquette et al. 1997). The wetland being used by the brood was determined through triangulation from known roadside locations. If error polygons encompassed more than one wetland, the wetland being used was verified by triangulating at closer range with a handheld antenna. We obtained visual observations of ducklings at approximately weekly intervals to verify that the radiomarked hen was still tending a brood. We excluded any hens that suffered total brood losses or were not tracked until their ducklings were 30 days old. Locations of brood hens greater than 30 days post-hatch were removed from analysis because hens with older ducklings spend relatively little time with their broods (Talent et al. 1983).

In July or August we took 1:5000 scale aerial photographs of each study site. Stereo pairs of photos were used to delineate and digitize wetland basins on each study site. Wetlands were visited in July or early August and individually classified as wet or dry and assigned to permanence classes according to Stewart and Kantrud (1971). Universal Transverse Mercator (UTM) locations were given to each wetland and each brood location. If the wetland was less than 5 ha, the brood location was assigned to the centroid of the pond. But if the wetland was larger than 5 ha, a more accurate brood location was used when available. The resulting dataset included a brood hen's geographic location at specific times for each day that she was radiotracked.

We calculated straight-line movement distances for these broods, but disregarded movements where the hen returned to the initial wetland on the same or following day. Mallard hens are known to leave their broods for short periods of time each day (Rotella and Ratti 1992b, Pietz and Buhl 1999); hence most of these round-trip moves likely excluded the brood. A brood's first move was calculated by using the UTM locations of the nest and the first brood wetland. We also measured the straight-line distance from the nest to the brood's final location at 30 days post-hatching.

A repeated-measures logistic regression analysis (PROC GENMOD; SAS Institute 1996) was used for modeling daily probability of interwetland

movements as a function of brood age (2-30 days), hatch date (90% range: 29 May to 20 July), and study area. We deleted one-day-old broods from this analysis since all 308 of them made an initial overland movement from their nest site to a first wetland. For broods that were radiotracked more than once per day, we retained only one daily location for analysis, but we preferentially retained the location demonstrating the longest interwetland movement. We included second-order interactions among age, hatch date, and study area, plus quadratic effects of age and hatch date to verify that relationships were linear. A backwards-elimination procedure was used to simplify this initial model. Non-significant ($P > 0.05$, based on Type III sums of squares) variables were deleted sequentially, beginning with the largest P-value, until all remaining variables were either significant or else included within a significant higher-order effect.

An analysis of covariance (PROC MIXED; SAS Institute 1996) with individual broods treated as random effects was used to model \log_e -transformed movement distance as a function of brood age, hatch date, study area, and all second-order interactions, plus quadratic effects of age and hatch date. A backwards-elimination procedure, similar to that described for movement probability, was used to simplify this model until all variables were significant or else included within a higher order effect. We also examined sources of variation in distance moved from the nest to the first wetland, and from the nest to the 30 d location. These latter analyses included only the effects of hatchdate, study area, and their potential interaction, since age was fixed and there were no repeated measurements to accommodate.

To explore sources of among-site variation in movement probability and movement distance, we conducted several post-hoc analyses where we replaced study area effects with eight covariates that described local wetland conditions; these included number of wetland basins, percent of basins inundated, total wetland acreage, and average basin size as calculated separately for seasonal and semipermanent wetlands.

RESULTS

Our data included 308 individual broods that made 1,881 total movements from hatch through 30 days of age (mean = 6.1, SD = 5.6, range: 1 - 54 movements per brood). The mean movement distance was 380 m (SD = 370, range: 10 - 5,540 m), with 94.3% of all movements covering less than 1 km.

Brood movements were recorded on 1,451 out of 8,295 monitoring days (17.5%). Daily movement probability was a function of study area, hatch date, age, and age² (Table 1). Study area effects were the most pronounced, with overall movement probabilities ranging from a low of 4% at Kutawa, SK, to a high of 47%

Table 1. Factors affecting daily movement probabilities of 308 mallard broods in 15 study areas in the Canadian Prairie Parklands, 1993 through 1997. Predictive equations from this model are plotted in Figure 2.

Factor	b	SE(b)	df	χ^2	P
Intercept	1.49	0.72	1	4.49	0.04
Study area	-0.42 ^a	--	14	52.23	0.0001
Hatch date	-0.011	0.020	1	6.87	0.009
Age	-0.092	0.004	1	20.58	0.0001
Age ²	0.0016	0.0006	1	7.51	0.006

^aAverage parameter value over all 15 study areas (equally weighted). Extreme sites are illustrated in Figure 2.

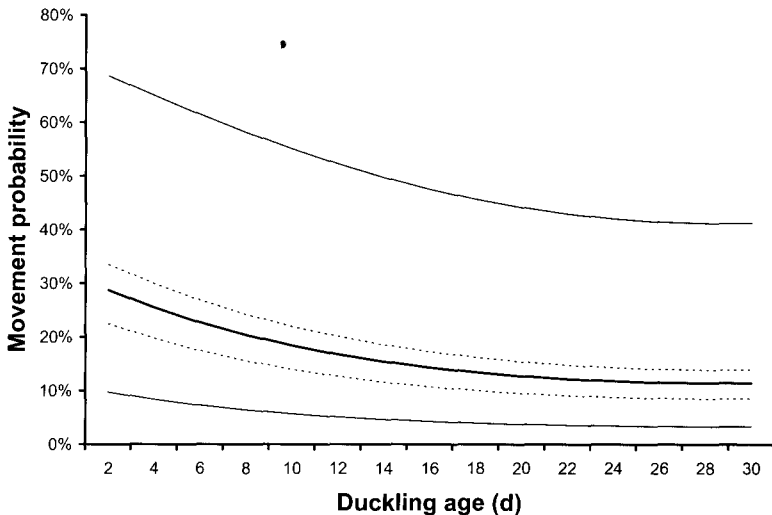


Figure 2. Age-specific probability of daily movement by mallard broods in the Canadian Prairie Parklands, 1993 through 1997. The central solid regression line represents the average predicted response over all 15 study areas at a median hatch date of 19 June. The upper and lower dashed lines represent predicted average all-site movement probabilities for early (29 May) and late (20 July) hatched broods, respectively (representing 5 and 95% cut-off dates for all hatched broods). The upper- and lowermost solid lines represent 19-June hatch date site-specific model predictions for Shoal Lake, MB and Kutawa, SK, the two most extreme study areas.

at Shoal Lake, MB (Fig. 2). Movement probability declined with age, but this effect decelerated as broods became older (Fig. 2). For an average brood with a median hatch date (19 June), movement probability was 29% at age 2 days versus 12% at ages 22 through 30 days. And finally, later-hatched broods were somewhat less likely to move than earlier-hatched broods. Predicted movement probability was 17% for a 16 day-old brood hatched near the beginning of the brood rearing period (29 May), versus 11% for a brood hatched near the end (20 July).

Mean movement distance was a function of study area, age, and a study area-by-age interaction (Table 2). The effect of age on mean movement distance was negligible over all sites combined, but most of the interaction effect seemed to be driven by data from Camp Lake (Fig. 3). Camp Lake broods moved about 470 m farther at age 30 than they did at age 1, whereas averaged across all 15 sites, 30 day-old ducklings moved only 20 m farther than did 1 day-old ducklings. With data from Camp Lake deleted, the age and area-by-age effects were no longer significant ($P > 0.19$), and movement distance was a function of study area alone ($F_{13,242} = 2.36$, $P = 0.005$). Aside from Camp Lake, predicted average movement distances were also relatively long at Kutawa and Parkside (440 and 430 m for 15 day-old broods), but for the remaining 12 study sites predicted average movements fell within a fairly tight range of 220 to 330 m.

Distance moved from nest sites to first wetlands averaged 350 m (SD = 390). The maximum first move was 2,350 m, but 93.6% of broods moved less than 1 km from their nests. First move distance increased with hatch date, but this relationship explained relatively little variation in the data ($\log_e \text{ distance} = 3.85 + 0.0093 \cdot \text{hatchdate}$; $F_{1,306} = 9.63$, $P = 0.002$, $R^2 = 0.03$). For a brood hatching on 29

Table 2. Factors affecting \log_e -transformed movement distances ($N = 2,192$) of 308 mallard broods on 15 study areas in the Canadian Prairie Parklands, 1993 through 1997. Predictive equations from this model are plotted in Figure 3.

Factor	b	SE(b)	df ₁ , df ₂ ^a	F	P
Intercept	5.54	0.12	1, 267	2,300.2	0.0001
Age	0.0006	0.0061	1, 2162	0.99	0.32 ^b
Area	0.080 ^c	--	14, 633	1.73	0.046
Area-by-age	0.0019 ^c	--	14, 2127	2.49	0.002

^aDegrees of freedom were calculated using the Satterthwaite method (SAS Institute 1996).

^bAlthough this factor was not significant, it was contained within a significant interaction.

^cAverage parameter values pooled across all 15 study sites (equally weighted). Extreme sites are illustrated in Figure 3.

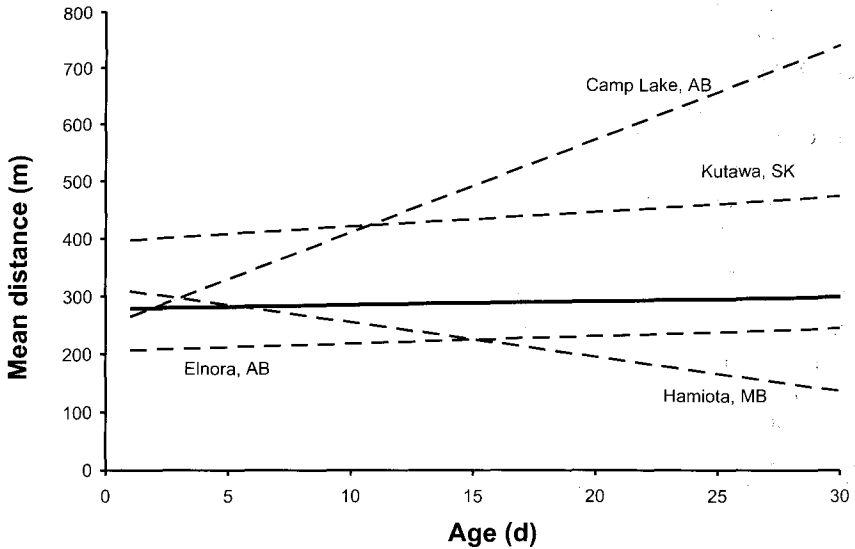


Figure 3. Predicted movement distance by mallard broods as a function of duckling age in the Canadian Prairie Parklands, 1993 through 1997. The solid line represents the pooled regression over all 15 study areas. Each of the four dashed lines represents a single study area that was most extreme (high, low) in terms of either area or area-by-age effects. The area-by-age effect was no longer significant when Camp Lake data were excluded from analysis.

May, the mean predicted nest-to-wetland movement was 190 m, whereas broods hatching on 20 July were predicted to move 310 m.

The straight-line distance between the nest and a brood's location at 30 days of age averaged 760 m (SD = 610). The maximum 30 day distance was 3,720 m, but 95% of distances were less than 2 km. The distance traveled from the nest to a brood's location at 30 days of age increased weakly with hatch date (\log_e distance = $4.93 + 0.0079 \cdot \text{hatchdate}$; $F_{1,306} = 7.43$, $P = 0.007$, $R^2 = 0.02$). Broods hatching on 29 May ended up 450 m from their nest site, on average, whereas broods hatched on 20 July ended up 680 m away.

The best wetland covariate for explaining movement probability was average size of semipermanent wetlands, which accounted for 26% of the among-site variability in movement rates (Table 3). Ducklings moved more often where there were large semipermanent wetlands, but this result was driven largely by Shoal Lake (Fig. 4). Number and total area of semipermanent wetlands accounted for 16 and 15% of the among-site variation in movement probability, respectively. For

Table 3. Relative ability of variables describing seasonal (III) and semipermanent (IV) wetlands to explain study-area specific variation in movement probability and movement distance of mallard broods across 15 study areas in the Canadian Prairie Parklands, 1993 through 1997.

Wetland variable	Movement probability			Movement distance ^a		
	%	χ^2	P	%	F	P
Study area	100.0	52.2	0.0001	100.0	2.6	0.001
Number III	0.2	0.1	0.78	3.2	1.2	0.28
Number IV	16.3	8.5	0.004	0.3	0.1	0.74
% flooded III	7.3	3.8	0.05	11.1	4.1	0.04
% flooded IV	6.1	3.2	0.08	12.6	4.6	0.03
Total acreage III	3.8	2.0	0.16	22.2	8.2	0.005
Total acreage IV	14.6	7.6	0.006	0.9	0.3	0.56
Mean size III	5.2	2.7	0.10	5.7	2.1	0.15
Mean size IV	26.3	13.8	0.0002	8.5	3.1	0.08

^aBased on the simpler movements model including only study-area effects (see text).

movement distance, total area of seasonal wetlands explained 22% of the among-site variation, whereas percent of semipermanent and seasonal wetlands retaining water explained 13 and 11%, respectively (Table 3).

DISCUSSION

There was more than 10 fold variation in movement rates among study areas, with overall average movement probabilities ranging from 4 to 47% among our 15 study areas. We attempted, through post-hoc analysis, to identify various landscape attributes that might explain some of this variation. Movement probabilities declined with increasing numbers of semipermanent wetlands, but increased with total acreage of semipermanent wetlands, but neither of these relationships were evident for seasonal wetlands. Movement probability also

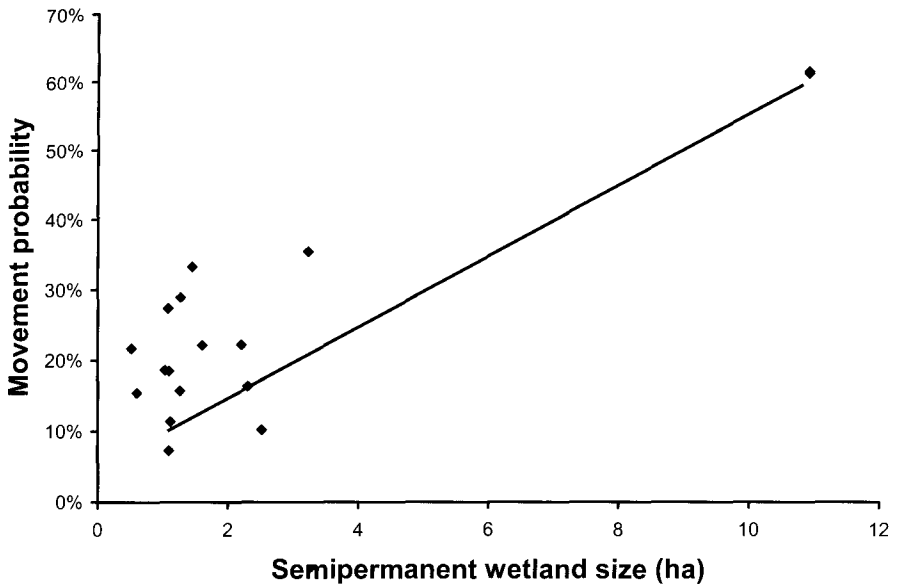


Figure 4. Among-site movement probability of mallard broods in relation to mean size of semipermanent wetlands over the entire study area, Canadian Prairie Parklands, 1993 through 1997. This single variable explained 26% of the among-site variation in movement probability, but the result was driven largely by the Shoal Lake study site (upper right).

increased with the percentage of seasonal and semipermanent wetlands retaining water. The strongest habitat relationship we discovered (out of eight examined) was a positive correlation between movement probability and mean size of semipermanent wetlands, which explained 26% of the study area effect using only one degree of freedom, but this was largely due to its ability to predict the high movement rate at Shoal Lake (Fig. 4). Contrary to North Dakota studies that have emphasized the need for seasonal wetlands (Talent et al. 1982, Krapu et al. 2000), our results suggested that semipermanent wetlands have greater influence on mallard broods in the Prairie Parklands. We concluded that having larger and better-flooded semipermanent wetlands increased the likelihood that broods will move to a new wetland, perhaps because such wetlands served as travel corridors that facilitate movements, but we were able to explain relatively little of the landscape-level variation in movement rates.

Very young mallard broods moved more than older broods, a finding that was consistent with several previous studies (Talent et al. 1982, Rotella and Ratti 1992b,

Dzus and Clark 1997). This seemed counterintuitive, since older ducklings with better locomotory skills should be better able to complete overland movements; however, their need to move presumably was reduced, since they already had ample time to find a high quality wetland.

Hatch date had a significant, albeit weak, effect on movement probability, with earlier-hatched broods exhibiting greater movement rates than later-hatched broods. Our among-site analysis showed that movement probability increased with increasing inundation of seasonal and semipermanent wetlands, and this also might explain why movement rates declined throughout the brood-rearing season (assuming that relatively more wetlands became dry throughout the breeding season), but we lacked seasonal data on wetland inundation with which to test this hypothesis directly.

Hatch date was the most consistent predictor of variation in movement distances among mallard broods. Later-hatching broods had slightly longer average moves, longer first moves, and moved greater distances from their nests to their 30 day locations. Declining wetland availability was probably the most likely factor causing broods to make longer moves later in the brood-rearing season. Typically, temporary and seasonal wetlands become dry during the summer, resulting in fewer habitat choices and increasing the likelihood of longer moves later in the brood-rearing season. Regional variation in wetland inundation explained reasonable amounts of among-site variation in movement distance, so it is reasonable to assume that seasonal changes in wetland availability would affect movement patterns. Nest-site selection might be another factor affecting seasonal variation in distance of first moves. Late-nesting mallard broods hatch farther from wetlands than early-season broods (Howerter 2003), so their first nest-to-wetland move necessarily will be longer.

Brood age was not a predictor of movement distance, except on a single study area (Camp Lake, AB). There was nothing particularly unique about this study site, and visual inspection of the scatterplot suggested that the relationship was driven by four broods with exceptionally short (< 75 m) initial movements. So even though older ducklings should have been better equipped than younger ducklings to make longer overland movements, there was no evidence to indicate that they did so.

Mallard broods moved several times throughout the brood-rearing period, but 79% of all moves were less than 0.5 km and 93% were less than 1.0 km. To manage habitats for the benefit of nesting mallards, a high density of suitable wetland basins must be located nearby, thereby minimizing potentially dangerous long-distance movements. Duckling mortality is very high during the first two weeks post-hatching (Ball et al. 1975, Talent et al. 1983, Mauser et al. 1994), and distance of overland moves might be correlated negatively with survival (Ball et al. 1975).

ACKNOWLEDGMENTS

Our project was funded by Ducks Unlimited Canada's Institute for Wetlands and Waterfowl Research. We thank R. Emery, B. Joynt, G. Mack, D. Shaw, J. Devries, and over 100 field technicians for assistance with data collection. J. Hare and R. Baydack provided helpful comments on an earlier draft of the manuscript.

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Received: 27 July 2005

Accepted: 25 March 2007

Associate Editor for Ornithology: Gregory A. Smith

