# AUTUMN FIELD-FEEDING PATTERNS OF THE WILD MALLARD DUCK *(Anas platyrhynchos)*

By

Garth Ball

A Thesis Submitted to the Faculty of Graduate Studies in Partial Fulfillment for the Degree of Master of Science

Department of Animal Science
Faculty of Agriculture
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Winnipeg, Manitoba

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ABSTRACT

Sixteen adult male and 8 adult female post moult mallards were equipped with radio transmitters, in a two year study ( 1977-6AHY-M and 4AHY-F; 1978 - 10AHY-M and 4AHY-F). Field-feeding was monitored at a lure crop and on adjacent grain fields. Ninety-two percent of the mallards radio-equipped were recorded at a field-feeding site at least once with 71% recorded field-feeding within one week. There was no significant difference in field-feeding activity between males and females.

In the morning during periods of rain, mallards field-fed 0.55h longer, arriving 0.30h later and departing 0.94h later than mallards field-feeding during clear weather. The morning field-feeding period was longer in duration than the evening field-feeding period.

Light intensity was the dominant climatological variable contributing to the arrival of mallards in the morning during periods of no rain (multiple $R^2$= 68.1%) and rain( $R^2$=69.5%). Light appeared to act as an initiating cue for morning feeding activity. A high correlation existed between duration of stay during periods of no rain( r=.0.815) and rain ( r= 0.860) suggesting that mallards remained longer at a field-feeding site in the morning by departing later, not arriving earlier.

Light intensity was also the dominant climatological variable contributing to the arrival of mallards in the evening amongst those mallards which field-fed in both the morning and evening ( $R^2$= 78.1%) and those which field-fed in the evening only ( $R^2$= 63.3%). In addition, light intensity was the only contributing factor in the evening for all mallards departing a field-feeding site ( $R^2$= 72.7%). Mallards were

never recorded field-feeding longer than 15 minutes after there was no measurable light.

The length of stay at a field-feeding site was highly correlated with arrival suggesting that mallards arrive at a field earlier in the evening to increase the time spent at the field-feeding site.

Amongst those mallards which field-fed twice per day, the departure from the field-feeding site in the morning and the time between the departure and arrival at the field-feeding site in the afternoon, contributed 77.9% to the overall variance. This suggested the success of the morning meal influenced the length of the evening field-feeding period.

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## DEDICATION

I dedicate this thesis to my wife, Pamela, for her constant love and support.

## ACKNOWLEDGEMENTS

To Dr. W. Guenter, Supervisor, Department of Animal Science, for his contribution to all aspects of this study, I would like to express my most sincere gratitude.

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# INTRODUCTION

Field-feeding on grain crops by waterfowl was first documented in the 1880's in Manitoba (Bossenmaier and Marshall 1958). By the mid-1940's the crop losses had become significant. The practice of leaving crops in swaths and then combining, versus the previous method of making stooks and then transporting the stooks to a common threshing area, provided waterfowl with an easily obtainable source of food.

The mallard, *Anas platyrhynchos*, and the pintail, *Anas acuta*, are responsible for the majority of waterfowl-related crop damage in the prairie provinces (Sugden 1976). Mallards are responsible for most of the damage because: they migrate later (Bellrose 1976); they tend to field-feed more zealously (Bossenmaier and Marshall 1958); they eat more grain per bird (Hammond 1950) and they are more abundant in numbers (Benning 1980, Brazda 1980, Caswell and Hochbaum 1980, Norman 1980).

Ducks damage crops by direct eating of the grain and trampling swaths. Trampling causes shelling of the seed head as well as making the swath difficult to pick up with a combine (Hammond 1950, Hochbaum et al. 1954). Damage increases when rain and humidity further prevent combining of the swaths (Bossenmaier and Marshall 1958, Renewable Resources Consulting Services 1969, MacLennan 1973).

Murton (1968) suggested two approaches for reducing crop damage: physical protection or biological control. Reducing the population below a "natural" level will not necessarily reduce crop damage (Murton 1974). Current waterfowl management programs in Manitoba are designed to maintain or increase the current mallard population

(Caswell and Hochbaum 1980). Under such circumstances innovative management practices are required. These will likely be focused on some facet of biology that can be exploited to influence the birds behaviour (Murton 1968). Sugden (1976) has stated "Not all factors that affect waterfowl damage or the success of control measures will be fully understood without more study of the behaviour of the birds".

The objectives of the two year study (1977 and 1978, August through October) were: 1) to determine whether meteorological factors had any significant effect on the daily field-feeding periods of the mallard; 2) to determine if field-feeding activity differed between the sexes; 3) to examine the relationship between the morning and afternoon field-feeding periods, and; 4) to obtain information concerning the distances flown, the crop type and the field condition (standing, swathed, stubble or cultivated) at the feeding site.

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# LITERATURE REVIEW

## I. Fall Field-feeding

### A. Initiation of field-feeding and crop preference

Mallards obtain food from both croplands and wetlands. Initial investigations into crop damage showed that aquatic foods were usually not sufficient to prevent field-feeding when swathed crops were available (Bossenmaier and Marshall 1958, Horn 1949, Munro 1952). Grain consumption increased when the availability of sago pondweed, *Potamogeton pectinatus*, was reduced in North Dakota (Hammond 1950). In England, mallards fed solely on brackish and salt water plant species only after croplands were no longer available (Olney 1964).

Recently, Sugden and Driver (1979) found that mallards obtain 70% of their food requirements from cereal croplands with the remaining 30% being from wetlands during the crop depredation season in Saskatchewan. The overall contribution of aquatic foods to field-feeding waterfowl diminished to less than 5% by mid-September. Further, they suggested that field-feeding was not initiated because of a lack of wetland food resources but rather, it was due to their close proximity to swathed fields, association with other field-feeding birds or local disturbances in and around the wetland.

The initiation of field-feeding appears to coincide closely with the termination of the flightless moult and the availability of swathed grain (Gollop 1949, Hochbaum et al. 1954). Bossenmaier and Marshall (1958) considered the presence of swathed grain important since they observed that mallards and pintails could distinguish between field types (standing or cut grain, stubble, burned or tilled fields and summerfallow) from the air.

Crop preferences of waterfowl have been determined by field observations and at feeding stations. Hammond (1961) suggested the preference order for swathed grains was durum wheat, barley, hard wheat and oats. In contrast, threshed hard wheat was preferred to threshed barley due to the lack of awns. The preference shown for durum over common wheat appeared to be due to the accessibility of the wheat kernels; durum wheat being more easily obtained from the seed head than common wheat.

In order to curtail widespread crop depredation, the government frequently sows or purchases fields of cereal grain near a waterbody used by depredating waterfowl as a roosting site. These crops are swathed and left uncombined for the waterfowl to feed on undisturbed, thereby preventing damage to adjacent cropland (MacLennan 1973).

### B. Daily field-feeding flights

#### 1. Schedules

A twice daily, morning and evening field-feeding pattern has been described by a number of researchers (Munro 1952, Hochbaum 1955, Sowls 1955, Bossenmaier and Marshall 1958, Winner 1959, Farney 1975, Cassel 1975). Further, all authors suggested that during inclement weather, the normal feeding pattern may be altered to include mid-day field-feeding flights. In the morning the departure time for field-feeding is usually before sunrise, often in complete darkness (tables 1 and 2).

Hochbaum (1955) suggested that the periodicity of field-feeding was governed by two cues, the "metabolic cue" and the "solar cue". The former was a response to hunger while the latter was in response to light intensity. In the morning, the "metabolic cue" can override the "solar cue" as the gizzards of ducks departing early in the morning from the marsh have been found to be empty (Hochbaum 1955, Bossenmaier and Marshall 1958). Apparently, these birds were hungry long before dawn.

Morning flights on clear days tended to be quite regular in relation to the amount of light present (Hochbaum 1955, Sowls 1955, Bossenmaier and Marshall 1958, Winner 1959). Bossenmaier and Marshall (1958) observed birds leaving later on cloudy days but apparently under the same light intensity as on clear mornings.

The evening flights to the fields can be more variable (table 2), although they generally took place in the latter part of the afternoon. Winner (1959) suggested that no relationship existed between the absolute value of the light intensity and the initiation time of feeding flights. However, Schoennagel (1963) suggested that in Germany, the mallards departure in the evening was directly related to the light intensity, with birds departing earlier on cloudy days than on clear days.

The apparent variability in the evening flights may be due to the "metabolic cue" described by Hochbaum (1955). He postulated that in the afternoon, the "metabolic cue" takes precedence over the "solar cue". Hochbaum noted that birds which follow a regular daily pattern

Table 1. Summary of arrival and departure times from the marsh and/or field for field-feeding ducks in the morning.

| Recorded time of flight | Remarks | Author |
|---|---|---|
| 1) Complete darkness | Few birds departed from the marsh | Gollop (1949) |
| Before sunrise | Heaviest departure from the marsh | |
| 2) Darkness | Departure from marsh | Munro (1952) |
| 15 min. to 40 min. post sunrise | Return to marsh | |
| 3) 50 min. pre-sunrise | Departure from marsh | Hochbaum (1955) |
| Pre-sunrise | Return to marsh began | |
| 4) Sky was dark | Departure from marsh | Sowls (1955) |
| Shortly after sunrise | Return to marsh | |
| 5) Began daybreak lasted less than 30 min. | Departure from marsh | Bossenmaier and Marshall (1958) |
| 30 min. to 3 hr. | Return to marsh | |
| 6) ½ hr. pre-sunrise | Departure from marsh | Farney (1975) |
| Shortly before sunrise | Arrival at field | |
| 1 hr. post sunrise | Departed from field | |
| 7) Pre-dawn movement | Departure from marsh | Cassel (1975) |
| As sky began to lighten | Arrive at field | |
| By sunrise | Most birds returned to marsh | |
| Continued to 2 hr. post-sunrise | Returned to marsh | |

Table 2. Summary of arrival and departure times from the marsh and/or field for field-feeding ducks in the afternoon.

| Recorded time of flight | Remarks | Author |
|---|---|---|
| 1) A period of 15-25 min. Shortly after sunset | Heaviest departure from the marsh | Gollop (1949) |
| 2) 1 hr. pre-sunset to 1 hr. post-sunset | Total duration of flight | Munro (1952) |
| 3) Greater than 1 hr. to several hours | Departure from marsh | Hochbaum (1955) |
| 4) 4:00 PM to 6:00 PM | Departure from marsh | Sowls (1955) |
| 5) 1 hr. or so pre-sunset<br>1½ hr. post-sunset | Departure from marsh<br>Departed from field | Bossenmaier and Marshall (1958) |
| 6) 205-9 min. pre-sunset | Departure from reservoir | Winner (1959) |
| 7) 1 hr. pre-sunset<br>Sunset to 30 min. post-sunset | Departure from marsh<br>Departed from field | Farney (1975) |
| 8) 2½ to 3 hrs. pre-sunset<br>Twilight to darkness | Began feeding<br>Heaviest feeding | Cassel (1975) |

probably received stimuli from the digestive tract. These stimuli caused the bird to seek a second meal in the afternoon. That is, the timing of the hunger stimulus could be dependent upon the success of the morning feeding (Hochbaum 1955, Winner 1959).

Bossenmaier and Marshall (1958) timed return flights to the marsh in the afternoon. These data suggest that the flights may be governed by light intensity. Nocturnal field-feeding appears to be uncommon (Hammond 1950, Bossenmaier and Marshall 1958, Farney 1975, Cassel 1975). However, Girard (1941) in Montana and Schoennagel (1963) in Germany reported regular nocturnal feeding. Hammond (1950) suggested that some night-time feeding took place on flooded fields, whereas Farney (1975) suggested that flooded fields were used only on moonlit nights.

Hammond (1950) suggested that birds feeding undisturbed on threshed grains could be satiated in 10 minutes, the average being 15 to 20 minutes. Similar times were recorded by Winner (1959) and Farney (1975) for ducks feeding undisturbed on swaths. Winner (1959) timed 25 separate occasions of field-feeding by ducks and recorded a mean feeding time of 15 minutes, with extremes being 5 to 30 minutes. Farney (1975) reported a slightly longer feeding time of 20 minutes.

2. Circadian rhythm

Aschoff (1966) considered the behaviour of an animal under normal environmental stimuli to be the result of interactions between genotype, experience and responses to concurrent environmental conditions. Under natural conditions, entrainment to a circadian rhythm occurs in the presence of a periodic factor in the environment. The light-dark cycle appears to be the most powerful stimulus with peak of activity coincident with dawn and dusk (Aschoff 1966). Under controlled light conditions, Winner (1972) established that the daytime activity pattern of the mallard is bimodal with both peaks being of about equal intensity. The ducks were inactive in the intervening photoperiod. Furthermore, he suggested that should the activity rhythm of the mallard be endogenous, it would be considered a true circadian rhythm.

3. The effect of weather on field-feeding flights

Besides light, other weather factors have been investigated to determine their effect on field-feeding. Investigators have considered environmental temperature, precipitation, humidity, wind velocity and barometric pressure.

Environmental temperature directly affects metabolic parameters in birds thereby influencing food requirements (Kendeigh, 1934). Activities of adult birds can be altered by ambient temperatures (Kendeigh 1934, Aschoff and Pohl 1970). Jordan (1953), using captive mallards, found the amount of food eaten varied inversely with environmental temperatures. Large variations in food intake by mallards were attributed mainly to differences in air temperature by Sugden (1979).

Farney (1975) and Winner (1959) concluded that temperature had little effect on the timing of field-feeding flights. However, during sub-freezing temperature, Bossenmaier and Marshall (1955) observed birds field-feeding throughout the day. At these low temperatures greater feed intake is required to maintain body temperature.

Mallards spent more time in the fields when it was raining or overcast (Cassel 1975, Sugden and Driver 1979). When the rain abated, the birds returned to roosting or gathering areas and resumed their normal schedules. These flights were not always initiated by hunger as observed by Bossenmaier and Marshall (1958).

Although Farney (1975) speculated that higher relative humidity may have delayed morning field-feeding flights, no correlation was established between prevailing barometric pressure and morning field-feeding flights. Hammond (1954) reported that a lightning strike near the feeding station was the cause for a temporary absence of birds from the station rather than other climatic conditions.

4. Distance flown to field-feeding sites

Waterfowl initially field-feed on fields nearest the water body used for a roosting site (Hochbaum et al. 1954, Bossenmaier and Marshall 1958) or nesting area (MacLennan 1973). Sometimes roosting areas on a lake were shifted to be in closer proximity to the preferred field (Bossenmaier and Marshall 1958). Later in the field-feeding season, ducks travelled to more remote fields in response to the harvesting of the nearby preferred fields (Hochbaum et al. 1954, MacLennan 1973). Also, harassment by the farmers, followed by the waterfowl hunting season further dispersed the birds (Bossenmaier and Marshall 1958). Table 3 tabulates the distances flown by waterfowl to field-feeding sites as documented by various authors. The maximum distance reported is 96.5 km (Hochbaum et al. 1954) although shorter flights of 2 to 20 km were more common.

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Table 3. Distance travelled by field-feeding waterfowl as documented by various authors

| Distance | Remarks | Author |
|---|---|---|
| 1) 4.8 to 6.4 km<br>16.1 to 24.1 32.2 km<br>96.5 km | Early part of season<br>Not uncommon in autumn<br>to wet fields | Hochbaum et al. (1954) |
| 2) 2.4 to 2.8 km<br>approximately 9.7 km | Mid August<br>Late August, September | Howard (1954) |
| 3) 16.1 to 24.1 km | Autumn | Hochbaum (1955) |
| 4) Up to .8 km<br>4.8 to 6.4 km<br>19.3 km | Early season<br>Common amongst those birds forced away from nearby fields<br>Maximum distance reported | Bossenmaier and Marshall (1958). |
| 5) Up to 9.7 km | Late in fall especially if durum wheat available | MacLennan (1973) |
| 6) 2.8 km<br>12.9 to 19.3 km | Occasional use<br>most feeding flights | Farney (1975) |
| 7) 4.8 km<br>Up to 12.9 km | Common<br>Rare | Cassel and Gulke (1976) |

## II. The Use Of Radio Telemetry In Monitoring Bird Movements

The use of radio telemetry allows the remote observation of an animal in its relatively normal physiological and psychological state, by interfering as little as possible with its normal routine of activity (MacKay 1970). Tester (1971) suggested that transmitter placement on waterfowl affected normal behaviour for a minimum of 2 days to a maximum of several weeks. The effect varied amongst individuals of the same species. Greenwood and Sargeant (1973) observed that captive mallards appeared preoccupied with the package and exhibited a partial aversion to swimming. However, movement and habitat use by mallards and wood ducks, *Anas sponsa* were not seriously affected (Gilmer et al. 1974). South African balck ducks, *Anas sparsa*, tended to preen longer, but habitat selection and use, feeding and breeding activities were apparently unaltered (Siegfried et al. 1977). However, it was difficult to monitor all aspects of the behaviour of radio-equipped wild birds to accurately assess abnormal behaviour (Gilmer et al. 1974).

# MATERIALS AND METHODS

## I. Study Area

The study area was Big Grass Marsh, Manitoba (Latitude 50° 12'N: Longitude 98° 50'W). Big Grass Marsh Game Bird Refuge is approximately 170.3 $km^2$ and encompasses several major wetlands within the marsh complex. The most northerly body of open water is Jackfish Lake, which was approximately 28.5 $km^2$ in area during this study (Fig. 1). The marking and monitoring of individual birds was done on and around Jackfish Lake.

Criteria for the selection of this section of the Big Grass Marsh for this study were:

1. a history of crop damage (Krentz 1960, Davies 1968, Jurick 1978);
2. the marsh is a moulting area for mallards and harbours large numbers of mallards well into the fall (Bidlake 1974, Collins and Boothroyd 1977);
3. the western flank of the marsh is where the majority of field-feeding occurs (Krentz 1959);
4. the study area is of very low relief with adequate access during dry weather via section right-of-ways, and;
5. lure crops were used for crop damage control.

## II. Equipment

### A. Transmitter packages

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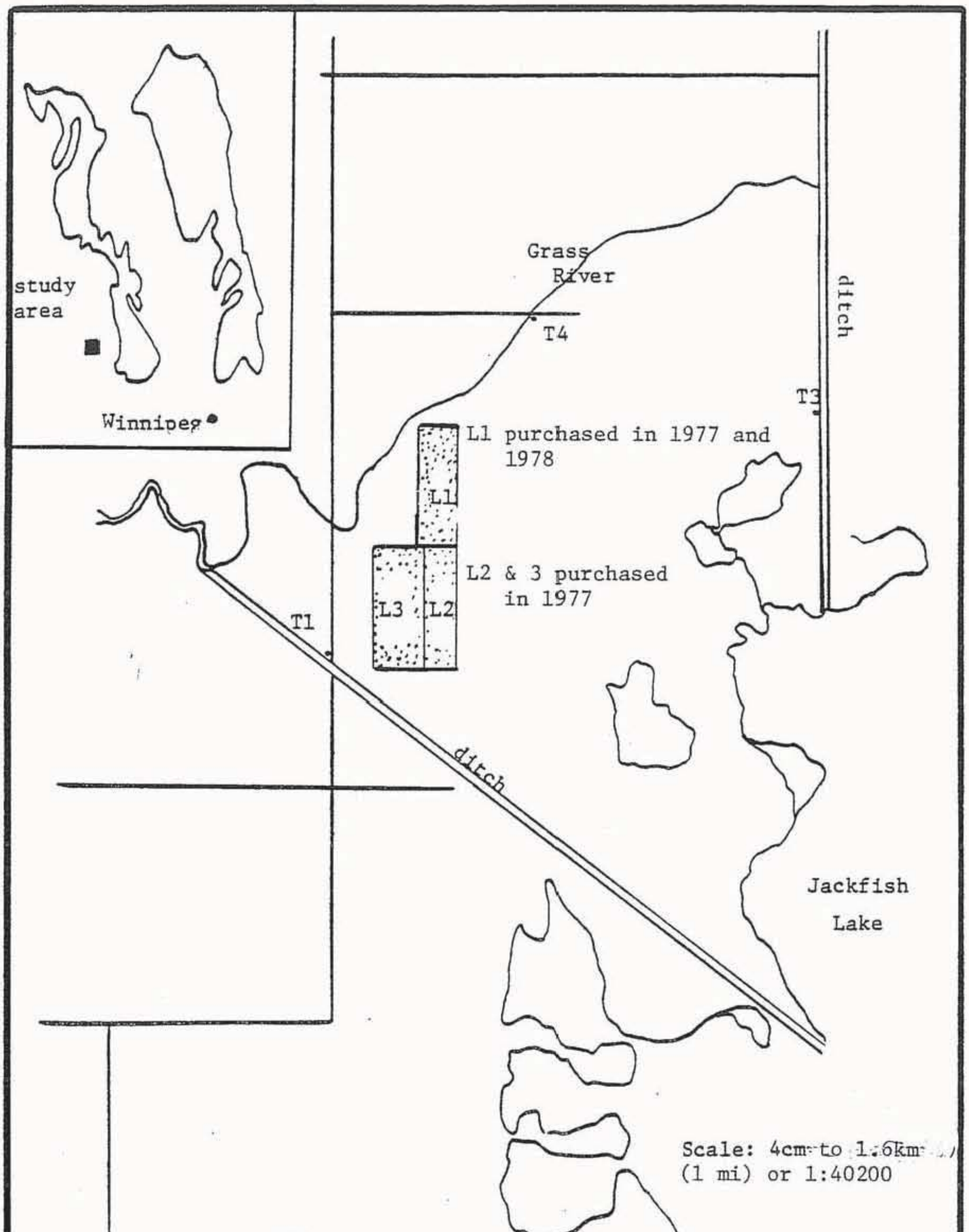
FIGURE 1. BIG GRASS MARSH STUDY AREA INDICATING LURE CROP (L1, L2, L3) AND STATIONARY TOWERS (T1, T2, T3, T4)




T1, T2 and T3 sites used in 1977.

T1 and T4 sites used in 1978.

Instrument Company Telemetry Manual (1974). Modifications concerning antenna attachment, the type of encapsulating material, batteries used, and the package and harness design are discussed in Appendix A1.

B. Receiver and antenna systems

The receivers used were AVM Instrument Company Model LA-12 receivers with a frequency receiving range of 164.425 to 164.725 MHZ. Three types of antenna systems were used:

1. a single 4 element general purpose yagi antenna tuned to 164 MHZ, supplied by AVM Instrument Company and mounted on 12.19 m stationary tower;
2. a single 11 element yagi antenna, Cushcraft Model A 449-11, tuned to 164 MHZ by Mr. Fred Anderka, Bioelectronics Technician, Canadian Wildlife Service, Ottawa, Ontario, mounted on a 9.14 m stationary tower, and;
3. a null-peak antenna system AVM Instrument Company, consisting of two 4 element yagi antenna joined by a cross boom. The antenna twin leads were connected to a null-peak box (AVM Instrument Company). They were used on a 15.85 m tower and on the mobile receiving units.

Details of antennae systems used in this study are outlined in Appendices A2 and A3.

C. Location Of Stationary Towers And Mobile Systems

Three masts were erected in 1977 on the western side of Jackfish Lake (Fig. 1). Two 15.85 m rotating towers were deployed in 1978, replacing the 1977 towers. The first was erected in the same location as T1 in 1977. The second tower T4 was placed 0.9 km northeast of the lure crop.

The mobile systems were established for three reasons: 1) to verify readings from the stationary towers, 2) to determine the whereabouts of mallards that had moved to other areas of the marsh and 3) to track mallards that were using feeding areas outside the range of the stationary towers.

D. Weather and Light Data

Weather recording instruments were obtained from the Canada Department of Atmospheric Environmental Services. They were:

1. A recording barograph unit which provided continual barometric pressure records in kilopascals (k Pa).
2. A hand-held anemometer, used to measure wind speed (km/hr).
3. A sling psychrometer, used to determine the relative humidity (%) and temperature ($^{o}$C).
4. A thermo-hygrograph was used in 1978 instead of the sling psychrometer.
5. A rain gauge, to record precipitation.
6. Light intensity was determined with a Gossen Lunasix 3 Light Meter (Gossen GMBH, Germany). Intensity was recorded on a scale of 0 to 22 using incident light readings. These readings were converted to lux units (lumen per meter$^2$) using conversion tables provided on the back of the light meter (Appendix Table B1).

In addition to these instrument readings, two other weather parameters were estimated: 1) the cloud cover present from horizon to horizon was estimated as a fraction (eg., 0/10, 1/10, 2/10, .. 10/10), and 2) wind direction was estimated in degrees of the compass.

The "baroslope", the slope of the barometric pressure over time, was calculated. For field-feeding observations made in the morning, (<1200 h) the baroslope was calculated by expressing the change in barometric pressure between 2200 h the previous night to 0600 h, divided by 8 for the intervening 8 hours. The baroslope for evening (>1200 h) field-feeding periods was calculated by expressing the change in barometric pressure between 1000 h and 1800 h, divided by 8 for the intervening 8 hours. A positive baroslope indicated weather patterns were under the influence of a high pressure weather system. A negative baroslope indicated the weather patterns were being influenced by a low pressure weather system.

During the 1977 field season, light intensity readings were taken coincident with the radio locating of a mallard. Wind speed, wind direction, relative humidity and temperature (sling psychrometer), presence of precipitation and cloud cover, were taken at one-half hour intervals. More frequent readings were taken if any of these variables appeared to be changing quickly. Daily high and low temperatures were obtained from the Grass River Weather Station located 5.6 km west of Jackfish Lake.

In 1978 light intensity was recorded at five minute intervals, wind speed and direction at 15 minute intervals. Relative humidity and temperature were recorded by a thermo-hygrograph at the Grass River Weather Station.

## III. Procedures

### A. Trapping and radio-equipping

Adult male and female mallards were caught in bait traps by Canadian Wildlife Service personnel at Big Grass Marsh. Radio-equipping took place once the field-feeding flight to the lure crop had established itself. The selection criteria for mallards that were to be radio-equipped were: 1) adult bird as determined by cloacal examination (Hochbaum 1942); 2) a complete regeneration of new feathers following spring molt so that the bird could fly, and; 3) a robust bird as determined by a subjective appraisal of its general condition.

Mallards were weighed using a drop scale, Accu Weight Model T-4 (capacity 2±.01 kg). The transmitter was secured (Appendix A1) to the bird using the method of Dwyer (1972).

### B. Radio-tracking

Radio location techniques using the single array antenna and the dual antennae null-peak system are described in the AVM Instrument Company Manual (1974). When thunderstorms were in the vicinity, radio monitoring was suspended for safety reasons.

### C. Statistical procedures

Initial examination of the data indicated that the observations could be divided up into three groups. These were: 1) a field was monitored both in the morning and evening and a mallard was observed in both periods; 2) a field was monitored morning and evening but a mallard appeared at the field during only one period; 3) a field was monitored only in the morning or evening and a mallard was observed in that period. The assumption was made that if a mallard was recorded field-feeding in both the morning and evening of the same day it field-fed nowhere else. In the latter two groups where a bird was recorded only once per day, it is understood that it could have fed in another field that was not monitored or it may have fed only once that day. The observations were divided into two groups of data for statistical evaluation: 1) those mallards which field-fed twice per day and 2) those which were observed once per day.

Statistical analysis was done using the "Statistical Package for Social Science" (SPSS), (Nie et al. 1975). Procedures used were students t test, simple correlation, and multiple regression.

Multiple regression procedures were used to determine which variables were or were not important in determining the arrival time, the departure time, and the duration of time spent at a field-feeding site. The object was not to generate a prediction equation but to discover which variables related to the dependent variable and to rank their importance by the amount of variation that they could explain in the overall variance of the dependent variable (Snedecor and Cochran 1967).

Multiple regression analysis was done using a "casewise" or "listwise" deletion of cases. Therefore, all correlations were based on a universal set of data. Once specific independent variables had been identified, a multiple regression with the reduced number of independent variables was applied to the data. In this way, an increase in the sample size was achieved. A distinction was made between statistically important variables and biologically important variables.

Only those variables contributing more than multiple $R^2$ change ($\Delta R^2$) >5% were selected to be rerun to achieve an increase in the sample size. Even though variables contributing less than $\Delta R^2$ <5% were statistically important ($P<0.05$) the actual contribution to the overall regression equation was thought to be biologically small.

Appendix B provides definitions of the variables used in the regression analysis.

# RESULTS AND DISCUSSION

## I. Effect of Transmitter

It was assumed for this study, that the transmitter package harnessed to the mallards had no effect on the birds physiology or behaviour. However, two of three mallards recovered showed some feather wear under the transmitter package. Both of these birds were equipped with the SB-2 transmitters. The third bird recovered showed no feather wear, possibly due to the transmitter being the lighter weight, SM-1 unit. The SB-2 units weighed 41 g whereas the SM-1 unit weighed 18.5 g. Gilmer et al. (1974) also reduced feather wear when using a lighter package. Slight feather wear on ducks has been observed both with the back mounted unit (Greenwood and Sargeant 1973) and the breast mounted unit (Gilmer et al. 1974, Siegfried et al. 1977). Greenwood and Sargeant (1973) suggested feather wear may be peculiar to waterfowl.

Weight loss was noted for one bird with the SM-1 unit, (14% in 40 days) and for another equipped with the SB-2 unit (17.9% after 17 days). The third mallard which was shot in Minnesota wore another SB-2 but was not available for weighing. Loss of weight by radio-equipped mallards has been previously reported by Schladweiller (1969) and Greenwood and Sargeant (1973), however only a weight loss of 47% and greater was considered to be critical for wild mallards (Jordan 1953b).

No behavioural observations of individual radio-equipped birds were obtained under field conditions. Data concerning the time between radio-equipping and the mallard's first appearance at a field-feeding site were the only indicators of possible behaviour modification.

Within one week of trapping (excluding the day of radio-equipping) 71% (17 of 24) of the birds were observed to field-feed. Seventeen percent (4 of 24) first visited a field during the second week and 4% (1 of 24) were first recorded during the third week. In the present study 92% (21 of 24) mallards were recorded field-feeding within three weeks which may suggest their behaviour was modified initially (Tester 1971) or the birds had not yet initiated the field-feeding habit at time of radio-equipping (Sugden and Driver 1979). Eight percent (2 of 24) were never recorded at a field-feeding site. These birds either died, only fed in the marsh or field-fed somewhere else and were never recorded.

The limited observations from these studies and observations of others indicate that the treatment (radio tagging) did not seriously bias the data.

## II. Location And Use Of Field-feeding Sites By Mallards

Barley, the first grain crop to mature and be swathed along the northwest corner of the marsh in 1977 and 1978, was the first crop to be utilized and was subsequently purchased as a lure crop (Figure 1). Mallards were observed field-feeding within a day of the completion of swathing. These fields were utilized until virtually all (96.3% in 1978) of the grain was consumed (crop survey report, Dennis Jurich - personal communication 1978).

Second to barley, wheat was the most abundant crop sown around the marsh. A field of hard wheat was purchased as a lure crop (Figure 1) in 1977. Field-feeding by waterfowl was also observed on feed wheat (variety - Glenlea) and buckwheat, however no feeding was observed on flax or rapeseed fields in the area.

The birds dispersed on other cropland surrounding the marsh once the lure crops had been consumed. Instead of one major flight as was the case with the lure crop, several flights were noted going in different directions to different feeding sites. The first fields visited by these birds were swathed fields, similar to the lure crop. Due to continual harassment by farmers, radio-marked mallards rarely fed on one particular crop for more than one or two feeding periods, before being scared away.

As combining continued and hunting pressure increased near the marsh, birds were observed flying up to 17.9 km west to feed on a swathed barley field in 1977 and 23 km in 1978 to a swathed wheat field. This is consistent with distances observed in other studies (Hochbaum et al. 1954, Bossenmaier and Marshall 1958, MacLennan 1973, Farney 1975).

Stubble fields were used by mallards on rare occasions when swathed fields were made less attractive because of scaring by farmers. On one occasion there were large numbers of ducks found to be feeding on a barley stubble field. The field had yielded approximately 4,313 kg/hectare (A. Schmidt, farmer, personal communication). The crop had been harvested when it was tough (14.8% to 17% moisture) due to prevailing damp weather conditions. The farmer estimated that because he harvested the grain too quickly, when it was tough, he had left 5% to 10% (215 kg/ha to 430 kg/ha) of the crop on the field. This is considerably more than the processing loss of 40.3 to 86.1 kg/ha expected under prudent combining practises (Dodds 1974). Large numbers of ducks fed on this stubble field for several days whereas minimal feeding was observed on a neighbouring stubble field which had been harvested more efficiently (communication with farmers). Food availability, appeared to be in sufficient quantities to reduce the incentive to travel further in search of swathed fields.

High usage of this stubble field may have been due to its close proximity to the marsh. The first ducks that utilized the field may have acted as decoys to other flights of ducks searching for a feeding site (thereby attracting them). This is consistent with Hammond's (1950) observation that ducks, if not disturbed at a field-feeding site, attract other ducks to settle in on the site.

III. Frequency of Field-feeding Flights

Table 4 lists the number of visits each mallard was observed to make to a field-feeding site as well as the total number of monitored periods that it could have been observed while it was in the study area. In 50% of the cases mallards did not field-feed at the monitored site. Thirty-three percent (33%) of the mallards utilized the feeding site less than 30% of the time whereas 37% of the mallards utilized the site greater than 70% of the time. No mallard was recorded utilizing a monitored site 100% of the time. Of 250 observations, 63% of the cases represented a mallard being observed field-feeding both the morning and evening (2 observations per day), 17% in the morning only and 20% in the evening only. Two hundred and four of the 250 observations were made on days when fields were monitored twice per day. Seventy-seven percent of these observations represented those mallards which field-fed both in the morning and evening while 13% of the observations were recorded in the morning only and 10% in the evening only.

Table 4. Summary of the observed field-feeding frequency of the radio-equipped mallards.

| Band no. | Maximum no. of possible field-feedings[2] | Actual recorded no. of field-feedings | Percent recorded feeding |
|---|---|---|---|
| 01 | 21 | 9 | 42.8 |
| 02 | 21 | 15 | 71.4 |
| 03 | 21 | 14 | 66.7 |
| 04 | 21 | 16 | 76.2 |
| 05 | 18 | 13 | 72.2 |
| 06 | 21 | 18 | 85.7 |
| 07[1] | 11 | 3 | 27.3 |
| 08[1] | 11 | 8 | 72.7 |
| 09[1] | 11 | 8 | 72.7 |
| 10[1] | 11 | 9 | 81.8 |
| 11 | 27 | 1 | 3.8 |
| 12 | 22 | 16 | 72.7 |
| 13 | 31 | 7 | 22.6 |
| 14 | 31 | 15 | 48.4 |
| 15 | 31 | 3 | 9.7 |
| 16 | 11 | 0 | 0.0 |
| 17 | 31 | 25 | 80.6 |
| 18 | 31 | 19 | 61.3 |
| 19 | 13 | 0 | 0.0 |
| 20 | 26 | 21 | 80.8 |
| 21[1] | 26 | 5 | 19.2 |
| 22[1] | 22 | 6 | 27.3 |
| 23[1] | 22 | 2 | 9.1 |
| 24[1] | 22 | 17 | 77.3 |
| TOTAL | 513 | 250 | 49.3 |

[1] Indicates females; all others are males

[2] Maximum no. of possible field-feedings is defined as the no. of times each bird could have been recorded had it appeared on the field-feeding site while the field was monitored. The monitoring dates for 1977 were 26 August to 10 September and for 1978 were 20 August to 8 September.

These data suggest that there is a great variation in the tendency for mallards to field-feed. Data were incomplete for those mallards which did not come out to feed at the monitored field. During the daylight hours, signal reception was very poor due to increased static and local interference obstructing the signal from a distant transmitter. The presence of an individual in the stuy area was usually determined at night when interference was at a minimum or when the mallard appeared at the monitored field. Still, this suggests that not all mallards field-fed on a regular basis (morning and evening) early in the crop depredation season. Hammond (1950) had also noted that not all mallards field-feed twice per day.

## IV. Field-feeding Characteristics of Mallards

### A. Differences among once only and twice daily field-feeding mallards

The arrival and departure times and the duration of stay at a field-feeding site were examined to determine if the differences between the means for those mallards recorded field-feeding once or twice per day were significantly different (Table 5). Only in the evening field-feeding period did significant differences exist. Mallards which field-fed twice per day arrived significantly ($P<0.05$) earlier in the evening ($0.45\pm0.07$ h pre-sunset) than those mallards which field-fed once per day ($0.18\pm0.10$ h pre-sunset), and remained at the field-feeding site for a significantly ($P<0.05$) longer time ($1.07\pm0.08$ h) than the mallards which field-fed once per day ($0.84\pm0.08$ h). There was no significant ($P>0.05$) difference in the departure times. Since only the time spent

Table 5. The arrival and departure from the field-feeding site and the duration[1] of time spent at the field-feeding site in the morning and evening for mallards feeding once or twice per day.

| Period | Variable | Field-feedings per day | Number of cases | Mean (hours) | Standard error | Range (hours) | Pooled Variance Estimate: Degrees of freedom | t value | 2-Tailed probability |
|---|---|---|---|---|---|---|---|---|---|
| Morning | Arrival[2] | Twice | 79 | -0.16 | 0.041 | -0.68 to 1.60 | 120 | 1.53 | NS[4] |
| | | Once | 43 | -0.11 | 0.064 | -0.53 to 1.97 | | | |
| | Departure[2] | Twice | 74 | 1.24 | 0.085 | -0.05 to 3.57 | 111 | 0.83 | NS |
| | | Once | 39 | 1.23 | 0.115 | 0.22 to 2.85 | | | |
| | Duration[1] | Twice | 74 | 1.41 | 0.083 | 0.05 to 3.50 | 111 | 0.51 | NS |
| | | Once | 39 | 1.34 | 0.105 | 0.20 to 2.73 | | | |
| Evening | Arrival[3] | Twice | 79 | 0.45 | 0.071 | 2.60 to -0.93 | 126 | 2.30 | $< .025$ |
| | | Once | 49 | 0.18 | 0.098 | 1.72 to -0.75 | | | |
| | Departure[3] | Twice | 71 | -0.65 | 0.039 | 0.90 to -1.15 | 118 | 1.00 | NS |
| | | Once | 49 | -0.66 | 0.045 | 0.28 to -1.23 | | | |
| | Duration[1] | Twice | 71 | 1.07 | 0.075 | 0.02 to 3.02 | 118 | 2.10 | $< .05$ |
| | | Once | 49 | 0.84 | 0.081 | 0.02 to 2.18 | | | |

[1] Duration is the difference between arrival and departure.

[2] Times corrected to sunrise (negative value indicates pre-sunrise).

[3] Times corrected to sunset (negative value indicates post-sunset).

[4] Not significant.

at a field-feeding site was recorded and not a rate of consumption (amount consumed per unit time), these data suggest that mallards which field-fed only once per day were more successful field-feeders. They could have maximized their effort by either feeding at a higher rate or locating on an area in the field where the swaths had previously been untouched. The maximum feeding efficiency (shortest time to be satiated) would be obtained by feeding at maximum rate on the highest density food patch. On the other hand this may represent mallards which have not fully developed a field-feeding tendency. Although most adult mallards have field-fed in previous years, they must choose between staying or leaving the security of the marsh in order to join others in the fields to feed. Those birds not fully conditioned to field-feeding may become nervous and leave prior to being satiated.

B. The influence of sex on field-feeding patterns

The arrival time, departure time and duration of time spent at a field-feeding site for male and female mallards were compared to determine if significant differences existed. The comparisons were performed on the two categories, those mallards which field-fed twice per day and those which field-fed once per day (Tables 6 and 7). No significant differences were observed ($P>0.05$).

In the morning among mallards that field-fed twice per day, males tended to arrive later, leave earlier and stay a shorter time than females, whereas, among those mallards that field-fed only in the morning, the males arrived earlier but stayed a shorter time than the females. In the afternoons, among those mallards field-feeding twice

Table 6. The influence of sex on the arrival and departure from the field-feeding site and the duration[1] of time spent at the field-feeding site in the morning and evening for those individuals that were recorded feeding both in the morning and evening on the same day.

| Period | Variable | Sex | Number of cases | Mean (hours) | Standard error | Range[3] (hours) | Pooled Variance Estimate: Degrees of freedom | t value | 2-Tailed probability |
|---|---|---|---|---|---|---|---|---|---|
| Morning | Arrival[2] | Male | 62 | -0.14 | 0.048 | -0.67 to 1.60 | 77 | 0.69 | NS[4] |
| | | Female | 17 | -0.21 | 0.070 | -0.62 to 0.47 | | | |
| | Departure[2] | Male | 59 | 1.20 | 0.093 | 0.13 to 3.57 | 72 | 0.87 | NS |
| | | Female | 15 | 1.39 | 0.204 | -0.05 to 2.80 | | | |
| | Duration[1] | Male | 59 | 1.35 | 0.093 | 0.50 to 3.50 | 72 | 1.36 | NS |
| | | Female | 15 | 1.63 | 0.180 | 0.32 to 2.75 | | | |
| Evening | Arrival[3] | Male | 62 | 0.43 | 0.081 | 2.60 to -0.93 | 77 | 0.53 | NS |
| | | Female | 17 | 0.52 | 0.153 | 2.08 to -0.38 | | | |
| | Departure[3] | Male | 57 | -0.64 | 0.047 | 0.90 to -1.15 | 69 | 0.58 | NS |
| | | Female | 14 | -0.70 | 0.051 | -0.32 to -1.13 | | | |
| | Duration[1] | Male | 57 | 1.05 | 0.084 | 0.02 to 3.02 | 69 | 0.61 | NS |
| | | Female | 14 | 1.17 | 0.167 | 0.53 to 2.83 | | | |

[1] Duration is the difference between arrival and departure.

[2] Times corrected to sunrise (negative value indicates pre-sunrise).

[3] Times corrected to sunset (negative value indicates post-sunset).

[4] Not significant.

Table 7. The influence of sex on the arrival and departure from the field-feeding site and the duration[1] of time spent at the field-feeding site in the morning and evening for those individuals that were recorded feeding in the morning only or the evening only.

| Period | Variable | Sex | Number of cases | Mean (hours) | Standard error | Range[3] (hours) | Pooled Variance Estimate: Degrees of freedom | Pooled Variance Estimate: t value | Pooled Variance Estimate: 2-Tailed probability |
|---|---|---|---|---|---|---|---|---|---|
| Morning | Arrival[2] | Male | 33 | -0.13 | 0.078 | -0.53 to 1.97 | 41 | 0.45 | NS[4] |
| | | Female | 10 | -0.06 | 0.108 | -0.43 to 0.72 | | | |
| | Departure[2] | Male | 30 | 1.16 | 0.121 | 0.22 to 2.85 | 37 | 1.08 | NS |
| | | Female | 9 | 1.45 | 0.298 | 0.38 to 2.78 | | | |
| | Duration[1] | Male | 30 | 1.28 | 0.114 | 0.20 to 2.73 | 37 | 0.91 | NS |
| | | Female | 9 | 1.51 | 0.255 | 0.22 to 2.63 | | | |
| Evening | Arrival[3] | Male | 35 | 0.18 | 0.110 | 1.25 to -0.75 | 47 | 0.00 | NS |
| | | Female | 14 | 0.17 | 0.209 | 1.72 to -0.58 | | | |
| | Departure[3] | Male | 35 | -0.67 | 0.049 | -0.05 to -1.07 | 47 | 1.40 | NS |
| | | Female | 14 | -0.56 | 0.096 | 0.28 to -1.23 | | | |
| | Duration[1] | Male | 35 | 0.87 | 0.091 | 0.17 to 1.92 | 47 | 0.75 | NS |
| | | Female | 14 | 0.74 | 0.174 | 0.02 to 2.18 | | | |

[1] Duration is the difference between arrival and departure.

[2] Times corrected to sunrise (negative value indicates pre-sunrise).

[3] Times corrected to sunset (negative value indicates post-sunset).

[4] Not significant.

per day, males tended to arrive later, departed earlier and remained a shorter time than females. Among mallards that field-fed in the afternoon only, males arrived about the same time as females but remained a longer time than females.

These comparisons were time related whereas Jordan's (1953a) study was consumption related. Using game farm and captive wild mallards, he determined that drakes consumed 15% more food than females during the fall and winter months. Sugden (1971) demonstrated a greater dry matter intake for males than females. Assuming that time spent on the field-feeding site is related to feed intake, the longer times spent by males would suggest a greater feed intake than for females in the present study.

C. The effect of rain on field-feeding patterns of mallards

The effect of rain on field-feeding flights was analysed for the morning only. Data collection for the afternoon was curtailed if it had been raining all day because of access difficulties to the monitoring sites. Also, lightning frequently accompanied afternoon rain showers. For the purpose of this comparison the data were grouped for those mallards which field-fed twice per day and in the morning only. The influence which rain had on the morning field-feeding patterns is presented in Table 8.

The mean arrival time during clear weather (no rain), 0.23±0.32 h pre-sunrise, was significantly ($P<0.001$) earlier than the arrival time when it was raining, 0.07±0.44 h post-sunrise. On clear days the departure time, 0.99±0.45 h post-sunrise was significantly ($P<0.001$)

Table 8. The influence of rain on the arrival and departure from the field-feeding site and the duration[1] of time spent at the field-feeding site in the morning field-feeding period.

| | | | | | | Pooled Variance Estimate | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Weather | Number of cases | Mean (hours) | Standard error | Range (hours) | Degrees of freedom | t value | 2-Tailed probability |
| Arrival[2] | Clear | 85 | -0.23 | 0.034 | -0.67 to 1.60 | 120 | 4.15 | < 0.001 |
| | Rain | 37 | 0.07 | 0.072 | -0.43 to 1.97 | | | |
| Departure[2] | Clear | 84 | 0.99 | 0.050 | -0.05 to 2.25 | 111 | 7.35 | < 0.001 |
| | Rain | 29 | 1.93 | 0.165 | 0.42 to 3.57 | | | |
| Duration[1] | Clear | 84 | 1.28 | 0.060 | 0.05 to 2.32 | 111 | 4.36 | < 0.001 |
| | Rain | 29 | 1.83 | 0.161 | 0.27 to 3.50 | | | |

[1] Duration is the difference between arrival and departure.

[2]Times corrected to sunrise (negative value indicates pre-sunrise).

earlier than the departure time, 1.93±0.89 h after sunrise, during rainy periods. Correspondingly, the mean duration of time spent at a field-feeding site during fair weather, 1.28±0.55 h, was significantly ($P<0.001$) shorter than the length of time during rainy weather, 1.83±0.87 h. Similarly, Sugden and Driver (1979) also observed that mallards spent more time out on the fields when it was raining.

Water is important for physiological processes in most birds and must be regularly available to prevent dehydration. Concerning feed intake, North (1978) stated three requirements for water by the domestic chicken during feeding: 1) to aid in softening the food; 2) to act as a carrier through the alimentary tract and 3) to aid in certain digestive processes.

The moisture content of grain lying in swath is dependent upon the prevailing weather conditions. Precipitation or high humidity can increase the water content of grain to a point of germination. Germinating barley, wheat and oats absorb 46%, 60% and 59.8% of their original weight in water prior to germinating. At this point the seed contents are semi-fluid (Stiles and Cocking 1969). In addition to absorbed water there is unabsorbed water on the surface of the seed and pools of water on the ground. These sources of water could reduce the urgency of the mallard to actively seek water in the marsh to aid in the digestive process. Consistent with this hypothesis was the observation of Sowls (1955) that mallards initiated drinking upon returning to the marsh.

On one occasion in the presence of rain, field-feeding mallards were observed walking over to the buckwheat crop adjacent to the lure crop, where the majority of the birds situated themselves on the buckwheat swaths and proceeded to preen. Mallards always vigorously preen during and after bathing; in this manner they wash and clean individual feathers and distribute oil to the feathers (McKinney 1965). The preening movements displayed by the mallards on the buckwheat crop may have been in response to the wetting of their feathers during the rain. These birds did not actively feed and this was verified by examining the swaths after their departure. The fact that mallards loaf and preen after returning to the marsh from stubble fields had been observed by Hochbaum (1955). Also, in commercial duck layer operations it has been observed that a sprinkler system is sufficient to provide enough water for cleaning and preening. Open water to bathe in is not required (W. Guenter - personal communication).

D. The differences between the duration of the morning and evening field-feeding period

The length of stay at a field-feeding site in the morning and evening during fair weather periods was compared to determine if the existing differences were significant. Evening data were divided into two groups, those mallards which field-fed twice per day and those which fed in the evening only (Table 9).

The mean duration at a field-feeding site in the morning, 1.28±0.55 h, was not significantly ($P>0.05$) longer than the duration in the evening, 1.07±0.63 h, for those mallards that field-fed during both periods. Among those mallards which field-fed in the evening only, the duration of stay, 0.84±0.57 h, was significantly ($P<0.05$) shorter

Table 9. The influence of morning and evening on the duration of the field-feeding periods during periods of no rain

| Variable | Group | Feeding times | Number of cases | Mean (hours) | Standard error | Range (hours) | Pooled Variance Estimate: Degrees of freedom | t value | 2-Tailed probability |
|---|---|---|---|---|---|---|---|---|---|
| Duration[1] | Group 1 | Morning only | 84 | 1.28 | 0.060 | 0.05 to 2.32 | 153 | 1.62 | NS[2] |
| | Group 2 | Evening (field-fed twice daily) | 71 | 1.07 | 0.075 | 0.02 to 3.02 | | | |
| Duration[1] | Group 1 | Morning only | 84 | 1.28 | 0.060 | 0.05 to 2.32 | 131 | 2.12 | < 0.050 |
| | Group 3 | Evening only | 49 | 0.84 | 0.081 | 0.02 to 2.18 | | | |

[1] Duration is the difference between arrival and departure.

[2] Not significant.

than the morning field-feeding period.

Possibly among individuals feeding in the morning, the hunger stimulus would be of equal intensity throughout the population, due to no field-feeding at night. In the afternoon, differences may exist in the population due to the success of the morning feeding period.

E. The influence of arrival and departure on the duration of field-feeding

The portion of the explained variance in duration of time spent at a field-feeding site as explained by the arrival and departure are presented in Table 10. During observation periods when there was no rain, the percent of association between arrival and duration was 30.7% ($P<0.001$) and between departure and duration was 66.5% ($P<0.001$). However, during periods of rain the duration of time spent at a field-feeding site is more greatly influenced by departure 74.0% ($P<0.001$). The arrival time has no influence on the time the mallards remain at the feeding site (4.9%, $P>0.05$). Therefore, the length of time spent at a field-feeding site in the morning is regulated by the departure time more than by the arrival time.

In the evening, the reverse is true in that the duration of time spent at a field-feeding site is influenced more by the arrival time than by the departure time. Among those mallards that field-fed twice per day and those which were observed feeding in the evening only, the arrival time significantly contributes 75.1% ($P<0.001$) and 79.3% ($P<0.001$), respectively. The departure did not have a significant effect on the length of time spent at a field-feeding site for twice daily field feeders, 4.8% ($P>0.05$), and the evening only field-feeders,

Table 10. The percent of association ($r^2$) between the duration of time (h) spent by mallards at a field-feeding site and the variables, arrival and departure.

| Independent variables | | Dependent variable | Percent of association ($r^2$) |
|---|---|---|---|
| Morning[1] | | | |
| During periods of no rain | (n = 84) | | |
| Arrival | | Duration | 30.7*** |
| Departure | | Duration | 66.5*** |
| During periods of rain | (n = 29) | | |
| Arrival | | Duration | 4.9* |
| Departure | | Duration | 74.0*** |
| Evening[2] | | | |
| Field-fed morning and afternoon | (n = 71) | | |
| Arrival | | Duration | 75.1*** |
| Departure | | Duration | 4.8 NS |
| Field-fed evening only | (n = 49) | | |
| Arrival | | Duration | 79.3*** |
| Departure | | Duration | 1.5 NS |

*P<0.05.

***P<0.001.

NS - Not significant

[1]Arrival and departures corrected to sunrise.

[2]Arrival and departures corrected to sunset.

1.5% ($P>0.05$).

F. Factors influencing field-feeding of mallards

The factors influencing field-feeding patterns determined by regression analysis are considered within the following general groupings:

1. Mallards field-feeding in the morning during periods of no rain,
2. Mallards field-feeding in the morning during periods of rain,
3. The arrival at and duration of field-feeding of those mallards which field-fed in the evening but were recorded at a field-feeding site both in the morning and evening,
4. The arrival at and duration of field-feeding of those mallards recorded feeding in the evening only and
5. All mallards departing a field-feeding site in the evening irrespective if they field-fed in the evening only or both in the morning and evening.

V. Morning Field-feeding Period

A. Arrival time of mallards during periods of no rain and rain

During clear weather two variables significantly ($P<0.001$) contributed 69.2% to the variation in arrival time (Table 11). Light intensity contributed 68.1% ($P<0.001$) whereas the contribution by relative humidity 1.1% ($P<0.001$) was biologically insignificant. Light intensity was also the only significant ($P<0.001$ contributor (69.5%) to the variation during periods of rain (Table 11). These results are consistent with Hochbaum's (1955) theory that a "solar cue" was

Table 11. The degree of association ($R^2$) of various variables as related to arrival, departure and duration of time spent at a field-feeding site in the morning during clear (no rain) and rainy weather

| Dependent variable | | | Independent variable(s) | | | |
|---|---|---|---|---|---|---|
| Variable | Weather condition | $R^2$ value for equation (%) | Variable(s) | $R^2$ contribution (%) | Sample size | Initial regression[1] (appendix) |
| Arrival | Clear | 69.2*** | Light intensity | 68.1*** | 72 | B2 |
| | | | Relative humidity | 1.1*** | | |
| | Rain | 69.5*** | Light intensity | 69.5*** | 30 | B3 |
| Departure | Clear | 61.0*** | Light intensity | 18.3*** | 49 | B4 |
| | | | Departure temperature | 14.8*** | | |
| | | | Low temperature | 14.1** | | |
| | | | Cloud cover | 7.9*** | | |
| | | | Relative humidity | 5.9* | | |
| | Rain | 93.6*** | Light intensity | 79.7*** | 24 | B5 |
| | | | Wind speed | 13.9*** | | |
| Duration | Clear | 57.4*** | Change[2] in light intensity | 50.4*** | 76 | B6 |
| | | | Change in barometric pressure | 5.5** | | |
| | | | Baroslope | 1.5** | | |
| | Rain | 72.8*** | Baroslope | 53.7*** | 22 | B7 |
| | | | Low temperature | 11.5*** | | |
| | | | Change in light intensity | 7.6* | | |

*P<0.05

**P<0.01

***P<0.001

[1]Regressed with all possible independent variables.

[2]Departure - Arrival.

required in the morning to initiate field-feeding. Even though the bird may be hungry, the "metabolic cue" is modified by the "solar cue" (Hochbaum 1955). Other researchers have noticed the coincidence of light and their initiation of the morning field-feeding flight (Sowls 1955, Bossenmaier and Marshall 1958).

On clear days the mean light intensity, 43.39 lux, at arrival was not significantly less than on days when it was raining, 97.54 lux (Fig. 2). Variability in the light intensity between individual mallards was not significant ($P>0.05$). As the significance approached the 5% level, a further examination between the means for each mallard was done. No significant difference existed between any two pairs of means ($P>0.05$). Although mallards arrived under similar light conditions, the arrival times were significantly ($P<0.001$) different. During clear weather the arrival time was 0.23±0.32 h before sunrise whereas when it was raining, the arrival time was 0.07±0.44 h after sunrise. Frequency distributions for both periods are presented in Figure 3.

Mallards arrived at the field-feeding site later in the morning on cloudy days but the light intensities at arrival are not significantly different from those on clear days. Apparently it is not the rain that is responsible for the later arrival but rather the cloud cover which significantly reduces the light intensity at dawn. Although Bossenmaier and Marshall (1958) did not measure the light present in the morning, they similarly observed that on cloudy mornings, ducks departed from the marsh later but apparently under the same light condition as on clear days. Farney (1975) also observed that adverse weather conditions

Figure 2. The observed temporal distribution for mallards arriving in the morning during periods of no rain and rain at a field-feeding site with respect to the amount of light present.

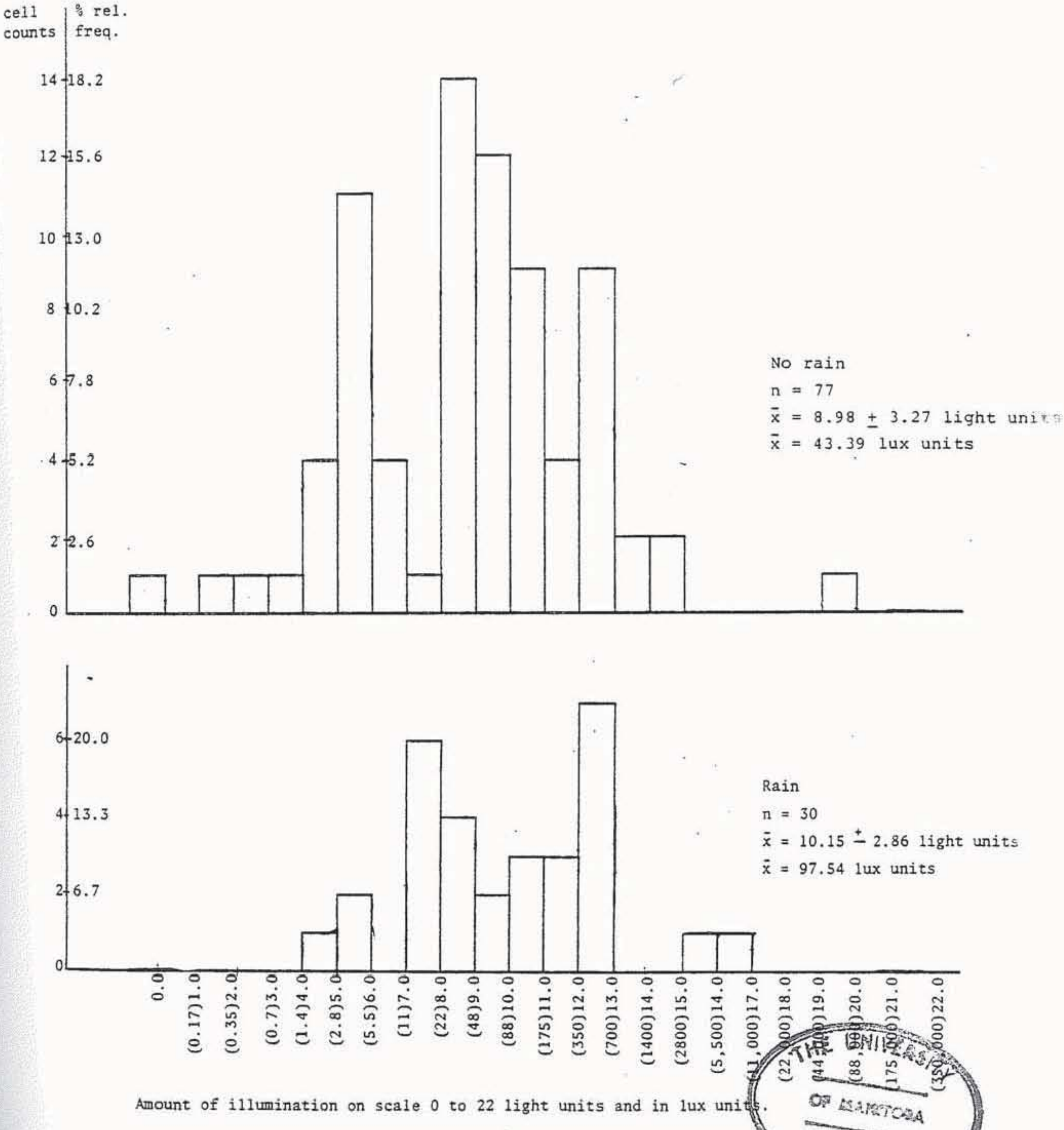


Figure 2. The observed temporal distribution for mallards arriving in the morning during periods of no rain and rain at a field-feeding site with respect to the amount of light present.

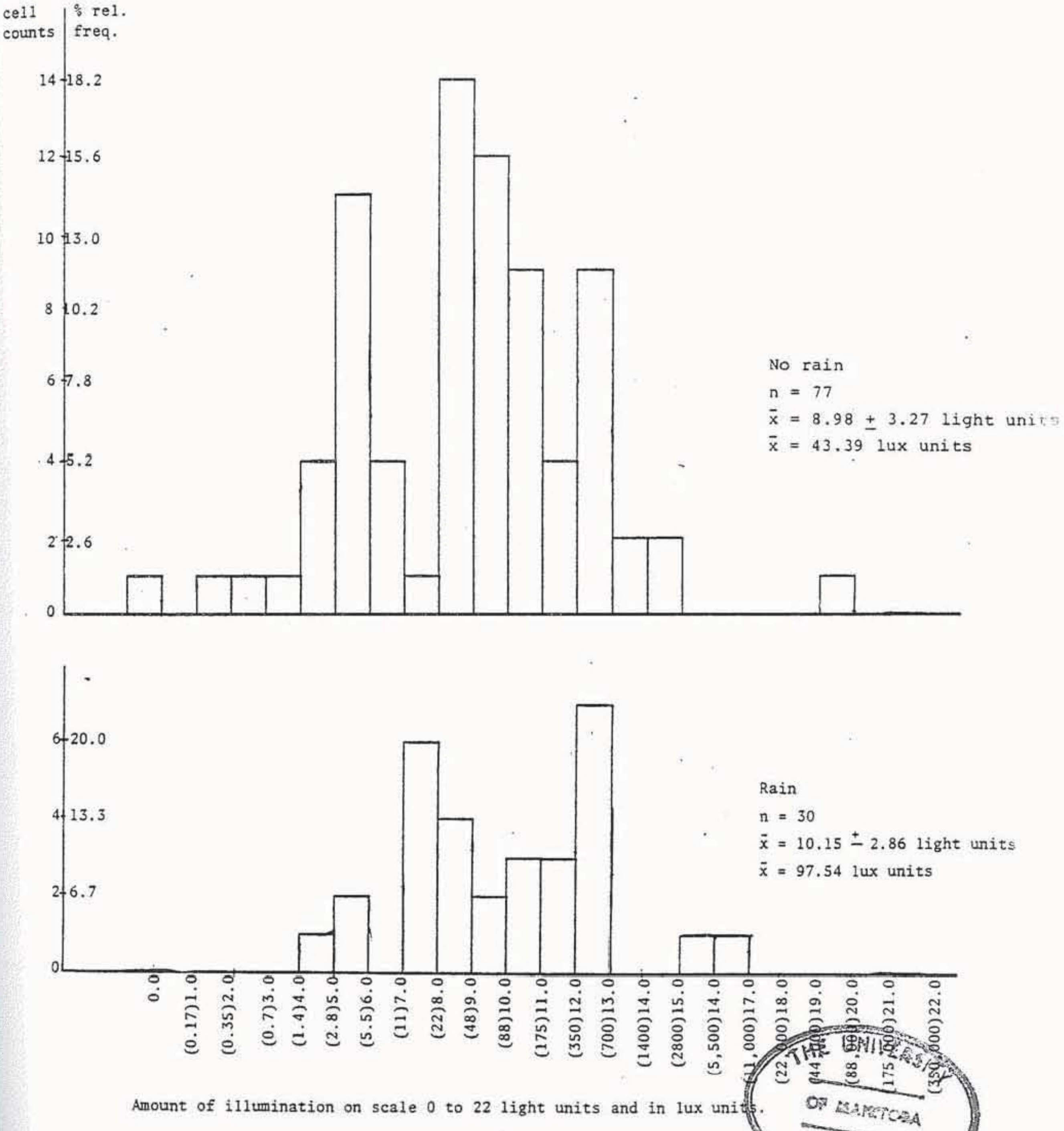
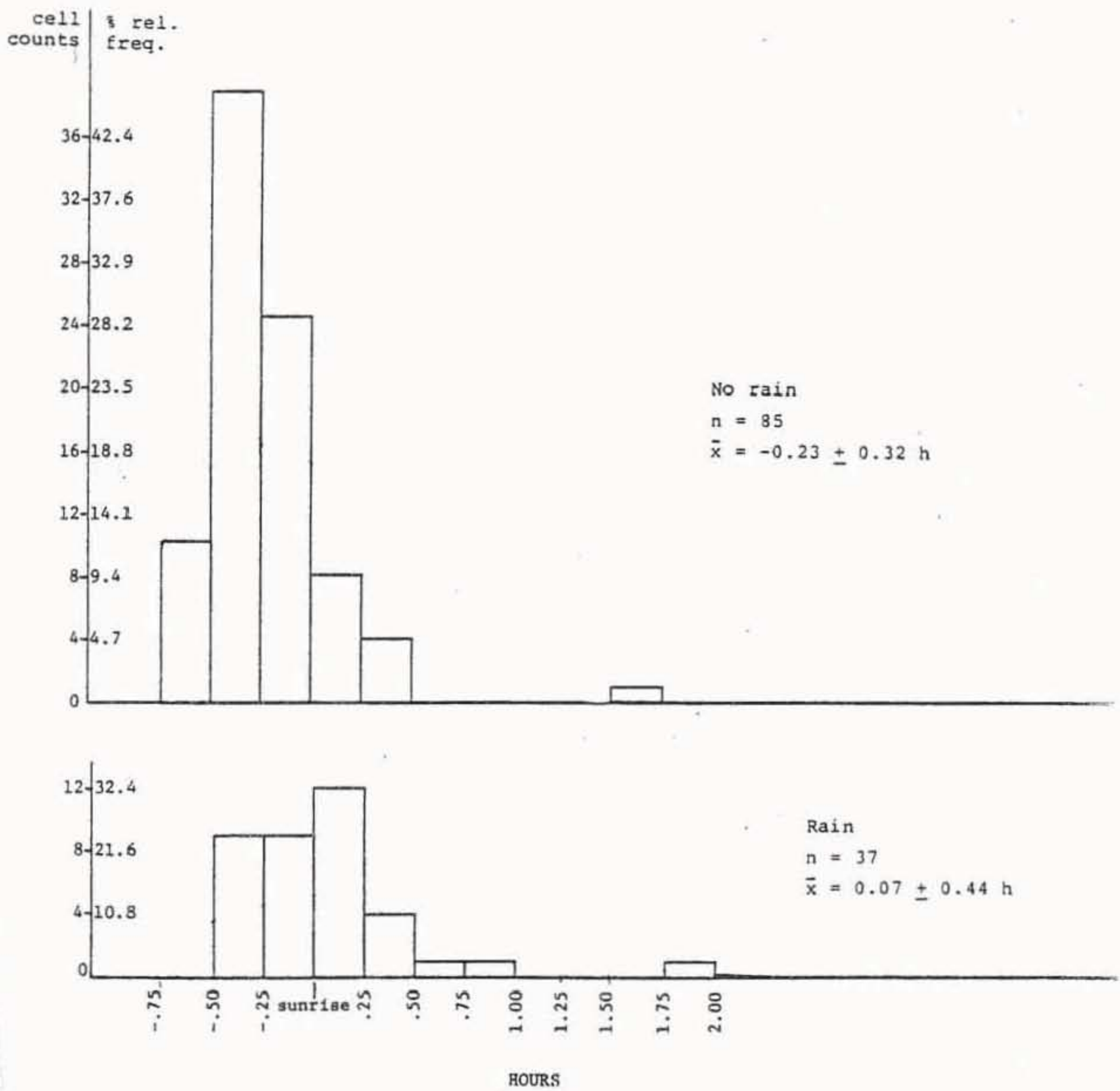


Figure 3. The observed temporal distribution for mallards arriving in the morning during periods of no rain and rain at a field-feeding site with respect to sunrise.[1]




[1] Negative values indicate pre-sunrise

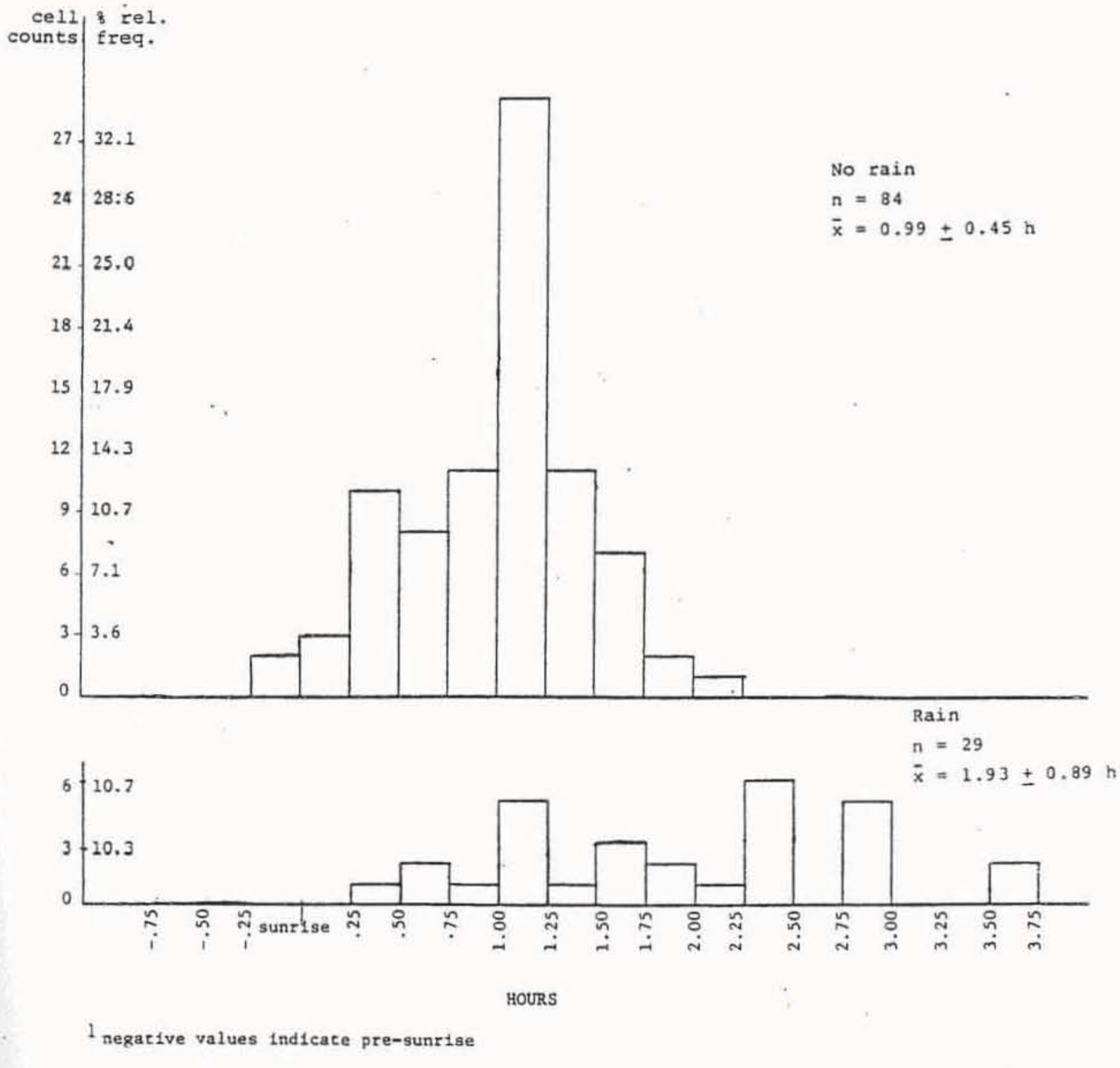
caused morning field-feeding flights to leave the marsh later.

In the present study, no other measured weather parameter had any significant effect upon arrival time. Similarly Farney (1975) concluded that neither wind velocity, temperature nor barometric pressure had any apparent effect on the initiation time of morning field-feeding flights from the marsh. However, he suggested that higher relative humidity readings may have caused flights to depart later. Data from the present study do not support this suggestion. The difference in the means of relative humidity between rainy periods (94.1±12.1%; maximum 100%) and during periods of no rain (93.3±7.9%; maximum 100%) were not significant, $P>0.5$ ($t = 0.558$, $df = 101$).

B. Departure time of mallards during periods of no rain

During feeding periods when it was not raining five variables significantly contributed 61.0% ($P<0.001$) to the variation in departure time (Table 11). The contribution of the variables were light intensity at departure 18.3% ($P<0.001$), temperatures at departure 14.8% ($P<0.001$), low temperature from previous night 14.1% ($P<0.01$), cloud cover at departure 7.9% ($P<0.001$) and relative humidity at departure 5.9% ($P<0.05$). When it was raining only two variables contributed 93.6% ($P<0.001$) to the variance (Table 1). These were light intensity at departure 79.7% ($P<0.001$) and wind speed 13.9% ($P<0.001$). The mean departure time during fair weather, 0.99±0.45 h post-sunrise, was significantly ($P<0.001$) earlier than during rainy periods, 1.93±0.89 h post-sunrise. Frequency distribution of the departure times for the two weather periods are presented in Figure 4.

Figure 4. The observed temporal distribution for mallards departing in the morning during periods of no rain and rain from a field-feeding site with respect to sunrise.[1]




[1] negative values indicate pre-sunrise

There was always a complete (10±0.0 units) cloud cover during periods of rain. The mean of 10±0.0 was significantly ($P<0.001$; $t = 5.952$, $df = 66$) greater than the cloud cover during periods of fair weather, 4.8±3.4.

The temperature at departure was significantly ($P<0.01$; $t = 2.67$, $df = 100$) milder during rainy weather, 11.7±2.2°C, than during fair weather, 9.8±3.4°C. Consistent with this pattern was that the low temperature from the night before prior to rainy periods, 9.5±2.4°C, was significantly ($P<0.01$, $t = 4.017$, $df = 100$) warmer than the low temperature associated with fair weather, 6.7±4.0°C. Also the change in temperature between arrival and departure of the mallards was reduced. Solar radiation is unable to penetrate the cloud cover and therefore less heating of the earth's surface takes place. Thus, the fluctuations in temperatures are reduced. The temperature change between arrival and departure from a field-feeding site was significantly ($P<0.001$; $t = 5.17$, $df = 96$) lower during rainy periods (0.7±2.0°C) than during periods of fair weather (2.1±2.3°C).

Wind speed was significantly higher ($P<0.01$; $t = 2.80$, $df = 105$) during rainy weather (10.3±9.2 kmh) than in fair weather (5.9±5.3 kmh). This would be expected as winds are usually associated with the passage of a low pressure system.

Humidity was not significantly different ($P<0.5$, $t = 0.558$, $df = 101$) during the early morning hours on fair days, 93.3±7.9%, than on rainy days, 94.1±12.1%. This was expected since in late August and September, the dew point was frequently reached on cool evenings. The relative humidity was frequently quite high until mid-morning. If it rained, a high relative humidity persisted.

The average light intensity at departure from a field feeding site during fair weather, 12, 138 lux (17.1±2.22 light units), was significantly ($P<0.001$; $t = 3.62$, $df = 98$) greater than the average light intensity, 3,537 lux (15.3±1.74 light units) during periods of rain. Although the light intensity was reduced during rainy periods, the magnitude of change from darkness, 0.0 light units, was large.

Light intensity was the only variable that had a large degree of change in the early morning hours during periods of rain. Also, temperature fluctuations were reduced and cloud cover was constant. The only other variable, besides light intensity, showing a greater fluctuation during rainy weather was the wind velocity.

In addition, departure during rainy weather was significantly ($P<0.001$) later. Therefore, it is apparent that rain or the presence of water has a significant effect on the field-feeding mallards. Further, the degree of association ($r^2$) between the length of stay and departure from a field-feeding site (Table 12) are both high and approximately equal in magnitude. This suggests that those mallards field-feeding during dry weather (versus wet weather) may be returning to the marsh in response to a water requirement. That is, to be able to determine the length of stay on the field-feeding site during dry weather, a measure of the water requirement of a bird would be necessary.

C. Duration of stay by mallards at a field-feeding site during periods of no rain

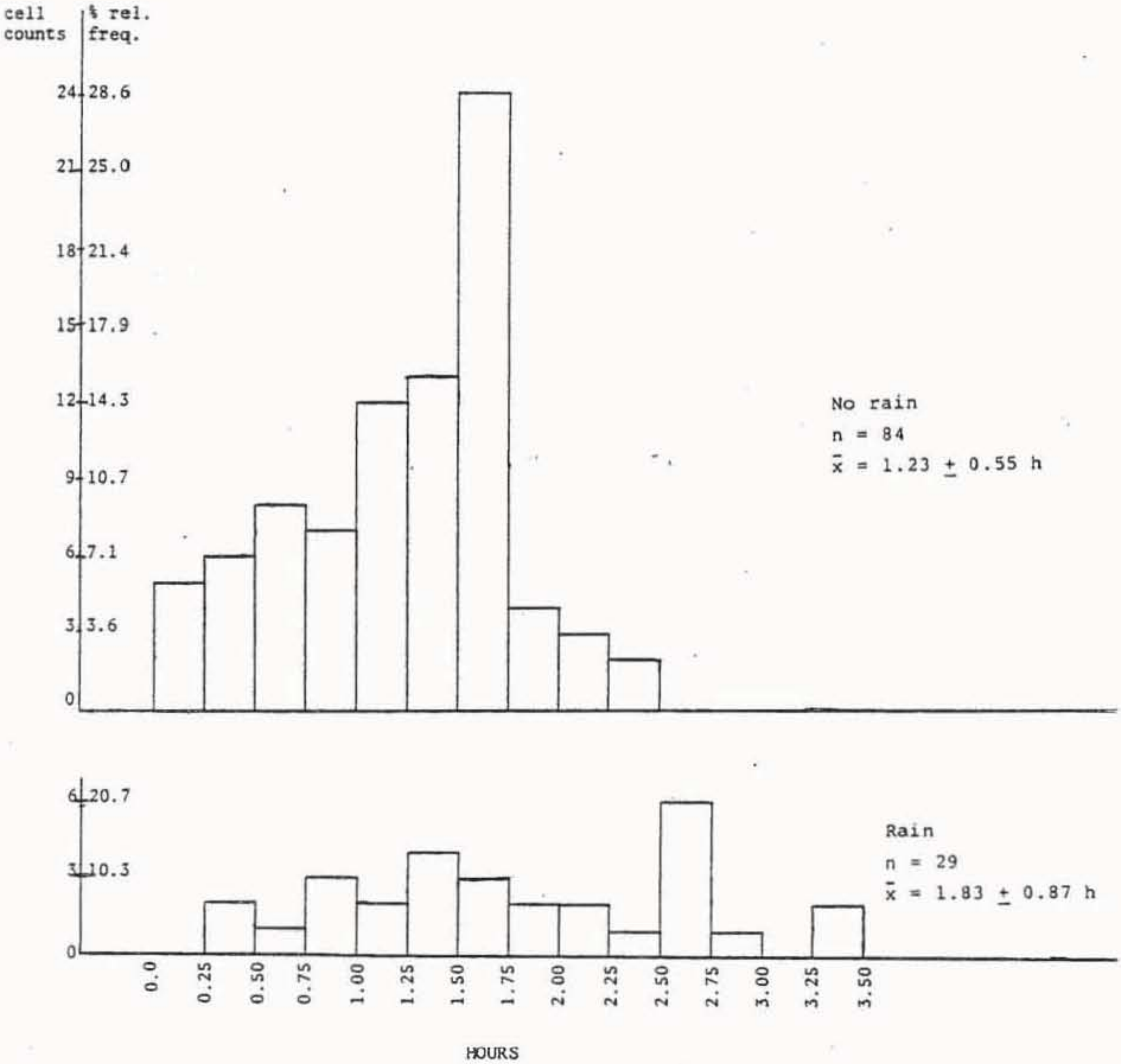
When it was not raining three variables significantly (P<0.001) explained 57.4% of the variance for the duration of stay at a field-feeding site (Table 11). Change in light intensity contributed the largest amount 50.4% (P<0.001) of the explained variance. In addition the change in barometric pressure and the baroslope contributed 5.5% (P<0.01) and 1.5% (P<0.01) respectively to the remaining explained variance. When it was raining three variables explained 72.8% (P<0.001) of the variance (Table 11). Individually they contributed, baroslope 53.7% (P<0.001), low temperature from the previous night 11.5% (P 0.001) and change in light intensity between arrival and departure 7.6% (P<0.05).

The duration of time spent at a field-feeding site, 1.23±0.55 h, was significantly (P<0.001) shorter during fair weather than during rainy weather, 1.83±0.87 h. These data are presented in a frequency distribution in Figure 5.

During fair weather, the mean change in light intensity, 8.2±3.99, contributed the most (50.4%) to the explained variance (57.4%). This represents a mean change in light intensity upon arrival of 8.9 light units to a mean of 17.1 light units at departure from a field-feeding site. Just greater than one-half the variance is explained by these weather variables.

In periods of rain, 83.2% of the variance is significantly (P<0.001) explained by three variables. Unlike in fair weather where change in light intensity was the dominant contributing factor, it is the least contributing in the presence of rain (7.6%). Baroslope contributes the greatest amount (53.7%).

Figure 5. The observed temporal distribution for the field-feeding duration of mallards in the morning during periods of no rain and rain.



Baroslope is an indicator of prevailing weather conditions. In periods of rain the slope was -0.23±.28 (negative slope) whereas in fair weather it was +0.16±0.29 (positive slope). This difference was significant at $P<0.001$ ($t = 6.16$, $df = 122$). A negative baroslope was indicative of the movement of a low pressure cell into the study area, hence the drop in barometric pressure over time. Rain is normally associated with cyclonic activity (low pressure cells) whereas anti-cyclonic activity (high pressure cells) is normally associated with stable (generally no rain) weather (Kendrew and Currie 1955). The positive baroslope indicated the movement of a high pressure cell into the study area, whereas the negative baroslope is representative of rainy weather. That is, the time spent at a field-feeding site is highly associated with rain.

When considering the arrival at, the departure from and the duration of time spent at a field-feeding site, it becomes evident that in the presence of rain a much higher percentage of the overall variance is explained. During fair weather the percentage explained is less (arrival: 68.1% versus 69.5%, departure: 61% versus 93.6% and duration 57.4% versus 83.2%). The data further suggest that the water requirements of the mallard (section IV E), whether they are for metabolic requirements or for washing and preening, help to determine the length of stay at a field-feeding site. Certainly other unmeasured variables in this study such as the influence of other members of the flock on an individual's feeding efficiency (Winner 1959) and whether the mallard was satiated (amount of food consumed by departure) (Hochbaum 1955) will greatly influence the feeding pattern.

Data for the present analysis were collected in the latter part of August and the early part of September. The mean temperature was 15.6°C. Temperatures, the change between arrival and departure and the low temperature from the previous night had a small effect on the time that mallards remained at a field-feeding site when it was raining. This effect was not noted during fair weather. However, Sugden (1979) conducted feeding trials outside in mid-September and early October when mean temperatures were 15.1°C and 6.4°C respectively. He determined that grain consumption varied with temperature; as well, wind velocity and relative humidity may have had some effect. The present study was conducted in moderately warm weather whereas Sugden (1979) compared data during a warm and cool period.

## VI. Evening Field-feeding Period

### A. Arrival time of mallards field-feeding twice per day and in the evening only

For those mallards that field-fed twice per day, two variables significantly influenced the arrival time contributing 87.0% ($P<0.001$) to the variance (Table 12). Individually light intensity contributed the most 78.1% ($P<0.001$) whereas cloud cover contributed 8.9% ($P<0.001$). For those mallards monitored in the evening only two variables contributed 70.4% ($P<0.001$) to the variance. Again, light intensity was the greatest contributor 63.3% ($P<0.001$). Wind speed contributed 7.1% ($P<0.001$).

Table 12. The degree of association ($R^2$) of various variables as related to arrival departure and duration of time spent at a field-feeding site in the evening for mallards field-feeding twice per day and in the evening only

| Dependent variable | | | Independent variable(s) | | | |
|---|---|---|---|---|---|---|
| Variable | Group | $R^2$ value for equation (%) | Variable(s) | $R^2$ contribution (%) | Sample size | Initial regression[1] (appendix) |
| Arrival | Twice | 87.0*** | Light intensity | 78.1*** | 49 | B8 |
| | | | Cloud cover | 8.9*** | | |
| | Evening only | 70.4*** | Light intensity | 63.3*** | 37 | B9 |
| | | | Wind speed | 7.1*** | | |
| Departure[2] | | 72.7*** | Light intensity | 72.7*** | 102 | B10 |
| Duration | Twice | 90.0*** | Difference between morning departure and evening arrival | 59.9*** | 62 | B11 |
| | | | Departure in the morning | 18.0*** | | |
| | | | Change[3] in light intensity | 12.1*** | | |
| | Evening only | 58.3** | Change in light intensity | 54.7** | 37 | B12 |
| | | | Change in temperature | 3.6 NS | | |
| | | | Change in barometric pressure | 0.01 NS | | |

***P<0.001 **P<0.01

NS Not significant.

[1]Regressed with all possible independent variables.

[2]No significant difference between groups.

[3]Departure - arrival.

There was significant ($P<0.05$) variability (analysis of variance) in light intensity among those mallards arriving in the afternoon who had also field-fed in the morning. This variability was due to birds #2 and #16 ($P<0.05$) whose mean arrival light intensity was significantly less than means of the other 17 mallards on whom observation had been made. That is, they arrived significantly later in the afternoon. Among those mallards field-feeding in the evening only, no sigficant variability was present in the arrival light intensity.

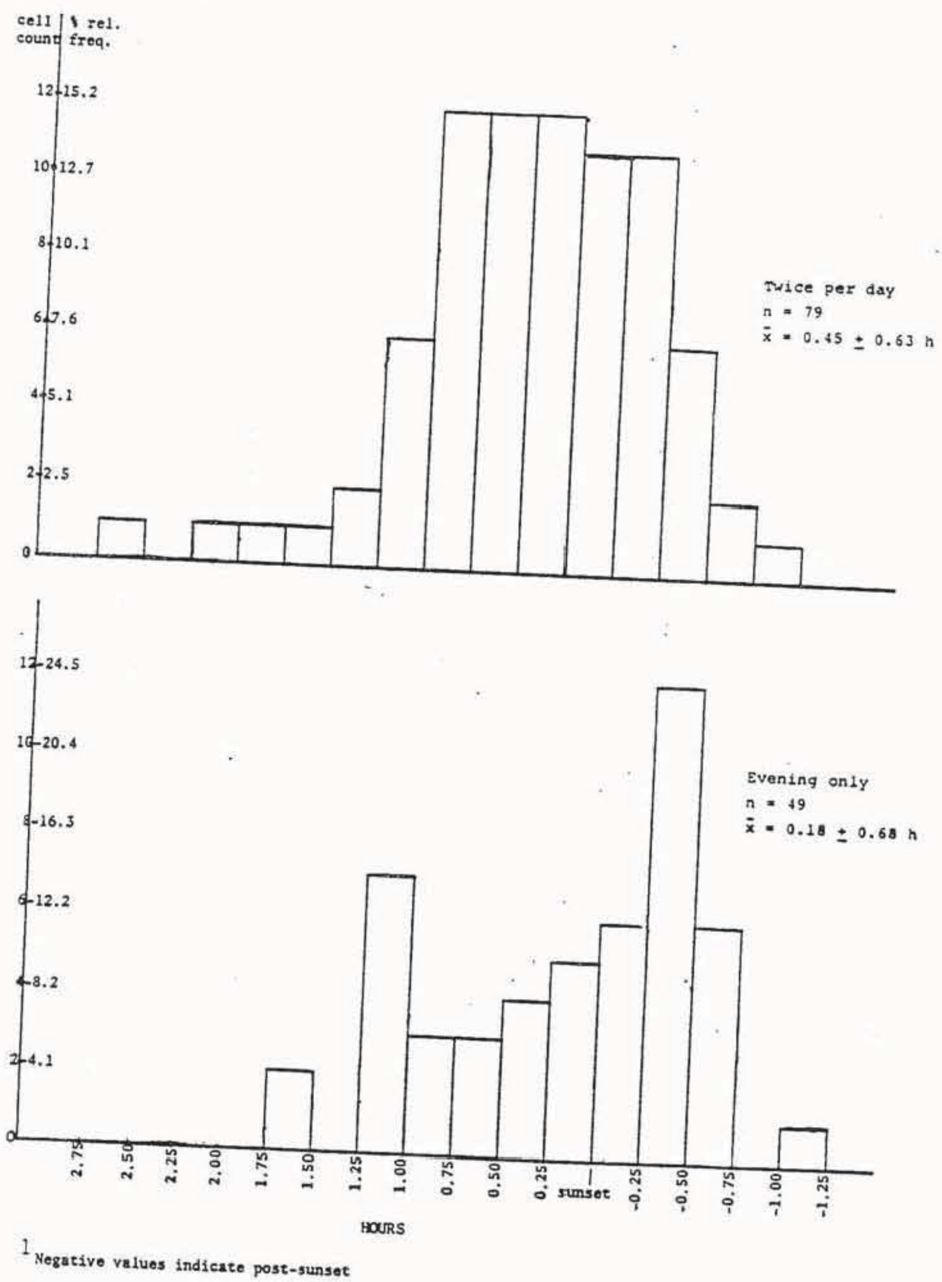
Light is to be the largest contributing meteorological factor, affecting the evening arrival time at a field-feeding site for both groups. Winner (1959) had suggested that the black duck (*Anas rugripes*) is more dependent than the mallard on the external light intensity cue to bring on the second period of feeding activity in the day. Bossenmaier and Marshall (1958) stated that field-feeding flights on clear days were not initiated until approximately sunset. These varied from an hour or so before sunset to shortly after sunset. Hochbaum (1955) found the second passage to take place in the "full light of day". Without measuring the light intensity it is difficult to define "full light of day". Even though the sun has not set, the actual light intensity decreases markedly as sunset approaches. In the present study, the mean light intensity for arrival time for mallards which fed twice per day was 1,336 lux (13.9 light units) and for mallards that fed once per day light intensity was 3,628 lux (12.1 light units). These readings are considerably less than light intensity recorded on clear days when the sun is at its zenith around midday, 88,000 to 175,000 lux (20 to 21 light units).

On only two occasions were arrivals monitored when there was no measurable light. In both cases, it was the same mallard and it stayed at the field-feeding site only one minute the first time and 12 minutes the second time. On three occasions all night vigils were maintained at the field-feeding sites. No field-feeding was recorded at these sites. Similarly, Farney (1975) did not observe any ducks spending the night in dry fields.

Frequency distributions of arrival times are provided in Figure 6. The mean arrival time for those mallards which fed twice per day was 0.45±0.63 h before sunset with the range being 2.60 h before sunset to 0.93 h after sunset. For those mallards which fed once per day, the mean arrival time was 0.18±0.68 h before sunset with a range of arrivals from 1.72 h before sunset to .75 h after sunset. Ninety-five percent of the mallards that field-fed twice per day arrived within 2.53 h whereas those mallards, which field-fed in the evening only, arrived within 2.7 h. Similarly, Hochbaum (1955) observed that the afternoon flight lasted more than one hour and frequently several hours. Sowls (1955) found that most mallards and pintails left the loafing bars between 1600 h and 2000 h, a period of 4 hours. The inconsistency of the afternoon departure was also noted by Bossenmaier and Marshall (1958). On the Winous Point, Lake Erie marshes afternoon flights were highly variable ranging from noon until after dark (Farney 1975).

In contrast to the variability of the evening arrival at the field-feeding site, the morning arrival at sunrise is much less variable. The morning arrival flight, 1.25 h, required less than one-half the time

Figure 6. The observed temporal distribution for mallards arriving in the evening at a field-feeding site for those which field-fed twice per day and those which field-fed in the evening only in respect to sunset.[1]




[1] Negative values indicate post-sunset

period, 2.53 h for birds that field-fed twice per day and 2.73 h for birds that field-fed in the evening only. Similarly, Hochbaum (1955) noted that the afternoon flight was not as precise as the morning flight.

Hochbaum (1955) speculated that the variability in the afternoon flight may be due to the success of the morning field-feeding period. Those birds which were the most successful in field-feeding near the marsh during the morning feeding period were the first to arrive back at the marsh, those which had to travel to several fields arrived later. In turn, those mallards arriving back early were first to initiate field-feeding in the afternoon, being stimulated by hunger. Winner (1959) suggested that birds which were not as successful in filling their crops in the morning feeding period initiated field-feeding earlier in the afternoon. This was a result of differential feeding success within a population feeding at any one field. That is, the afternoon flight was more of a response to a "hunger cue" (Hochbaum 1955) which in turn varied amongst individuals within a population due to the success of the morning meal. In contrast the mallards were hungry in the morning but did not depart from the marsh until there was sufficient light intensity. As a result, there was a more uniform hunger response within the population which led to a more precise morning field-feeding flight. The "light cue" took precedence over the "hunger cue" in the morning (Hochbaum 1955).

B. Departure time of mallards

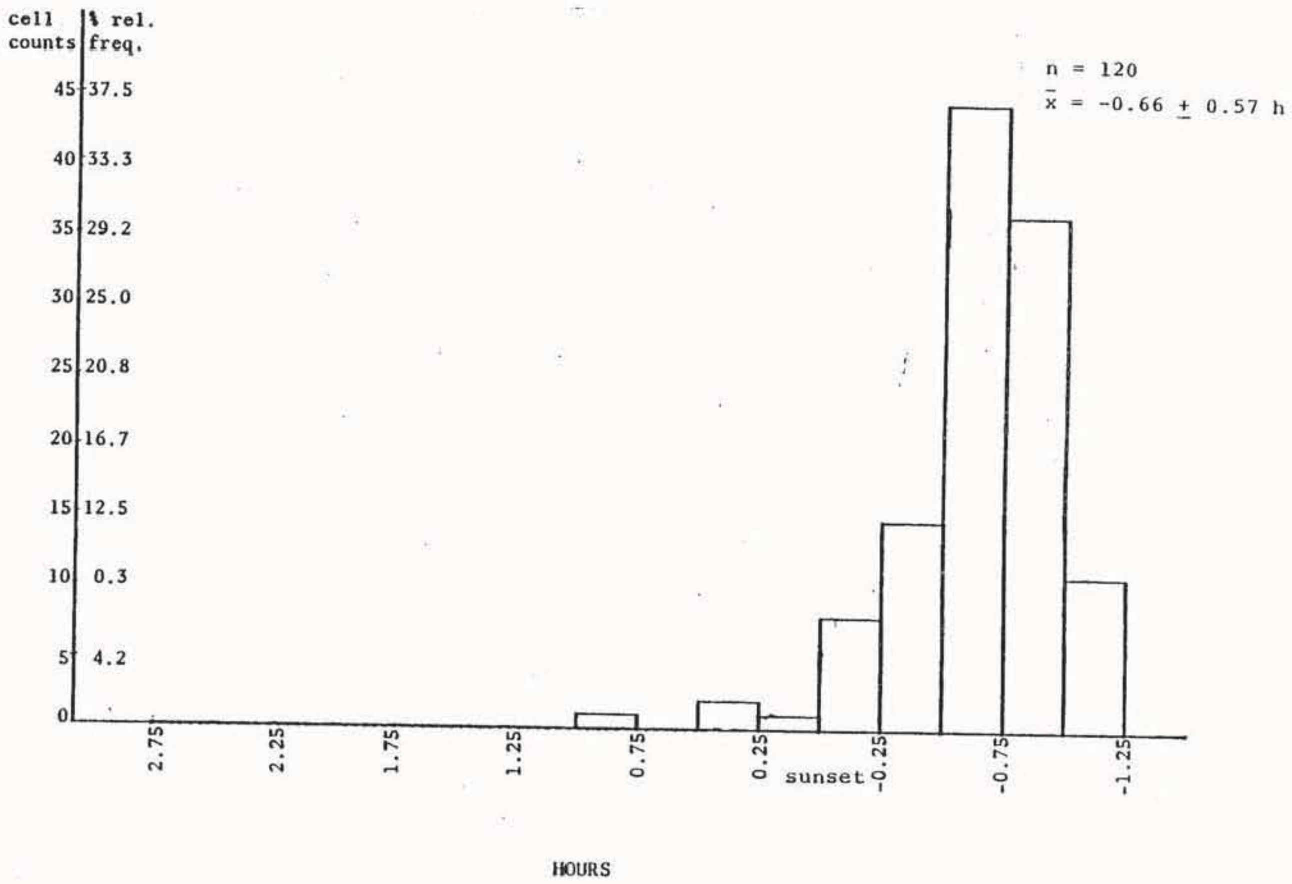
The evening departure times by mallards that field-fed twice per day and those that were monitored field-feeding in the evening only were not significantly different (section IV A). Therefore, all mallard departures were analysed together. A frequency distribution of departure times is provided in Figure 7. The mean departure time was .66±0.57 h after sunset.

Light intensity, the only significant variable, contributed 72.7% ($P<0.001$) to the overall variance (Table 2). A frequency distribution for all mallards departing from a field-feeding site in the evening with respect to the amount of light present is provided in Figure 8. There was no significant variability in the arrival time (analysis of variance) amongst individual mallards.

Although mallards were observed field-feeding into darkness when there was no measurable light, these birds remained only a few minutes after which they returned to the marsh. Mallards feeding in a period of no measurable light had all arrived during measurable light except for the two previously documented cases where birds arrived in the evening during darkness. The fact that the return flight to the marsh may be governed by light intensity had been previously suggested by Bossenmaier and Marshall (1958). There were no documented cases of mallards field-feeding into darkness for more than one-quarter of an hour.

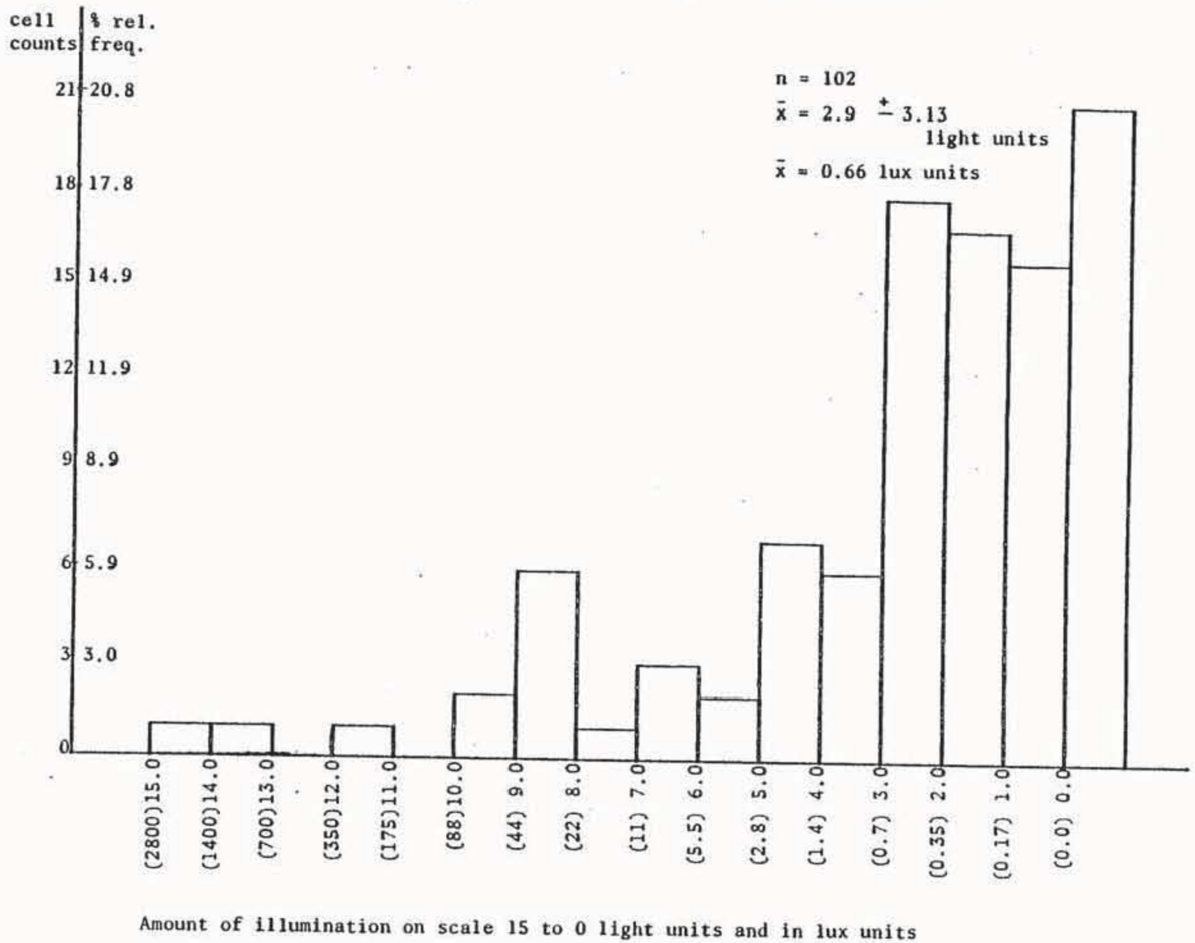
In the evening 1.28 h were required for 95% of the mallards to depart a field-feeding site. Whereas, in the morning during fair weather 95% of the departure took approximately 50% longer to complete, 1.78 h. This is consistent with previously presented data that mallards alter the length of stay at a field-feeding site in the morning by altering the departure time. The reverse is true in the afternoon when

Figure 7. The observed temporal distribution for mallards departing in the evening from a field-feeding site in respect to sunset[1].




[1]negative values indicate post-sunset

Figure 8. The observed temporal distribution for mallards departing in the evening with respect to the amount of light present.



duration of stay is governed by the arrival time. Therefore, it would be expected that the departure in the evening would be more punctual than in the morning.

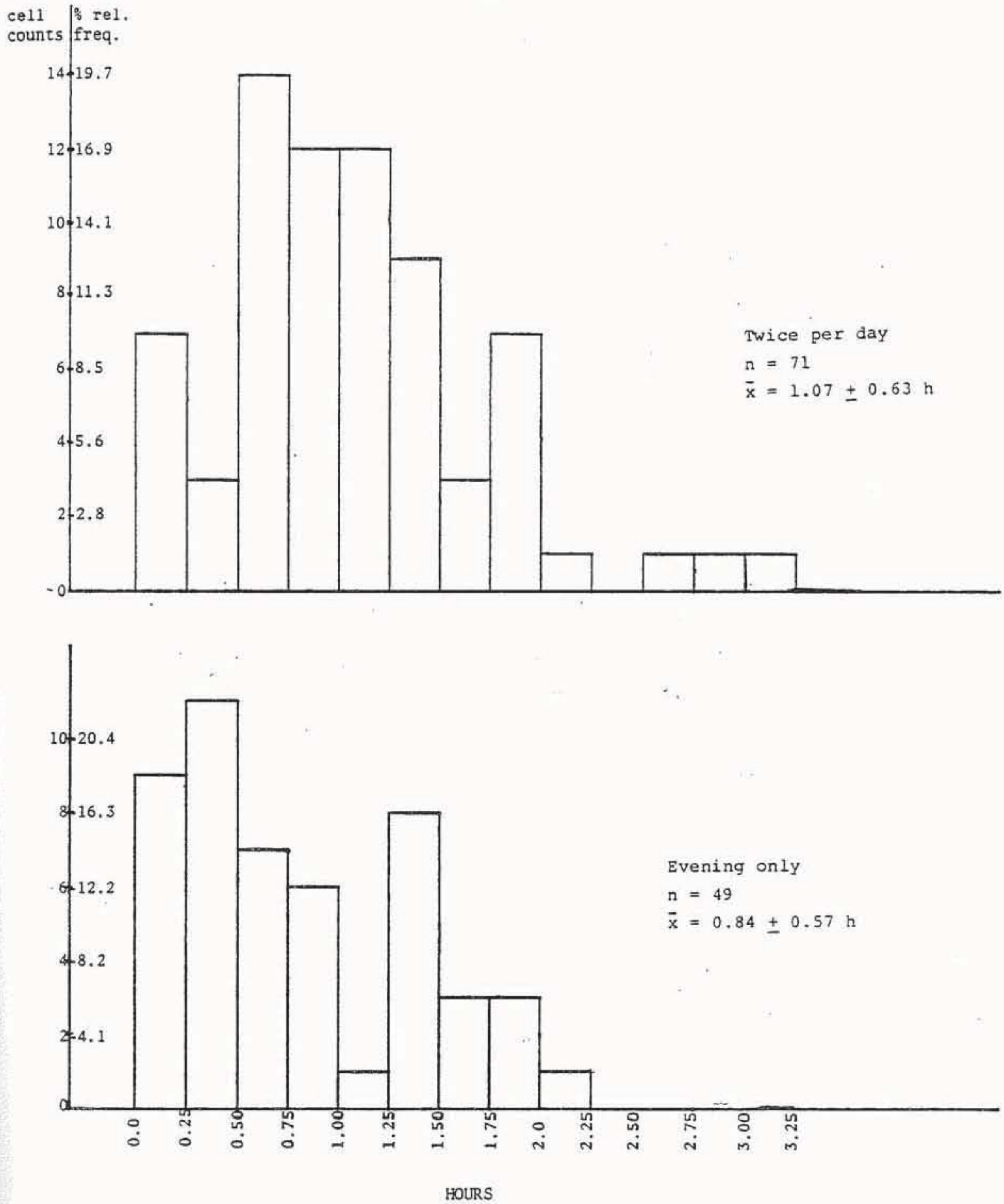
C. Duration of stay at a field-feeding site by mallards field-feeding twice per day and in the evening only

For those mallards that field-fed twice per day three variables contributed 90.0% ($P<0.001$) to the overall variance (Table 12). Two of the contributing variables were related to the morning feeding period, time difference between morning departure and evening arrival 59.9% ($P<0.001$) and departure from a field-feeding site in the morning 18.0% ($P<0.001$). The third and least contributing variable was change in light intensity between arrival and departure, 12.1% ($P<0.001$).

For those mallards monitored in the evening only, three variables contributed 58.3% ($P<0.001$) to the variance. Of the three variables change in light intensity between arrival and departure explained the greatest amount of the variance 54.7% ($P<0.001$). The contribution of the other two variables was non-significant, change in temperature 3.6% ($P<0.25$) and change in barometric pressure 0.01% ($P<0.25$).

Frequency distributions of the duration of feeding times in the evening for those mallards which field-fed twice per day and those which field-fed once per day, in the evening only are presented in Figure 9. The mean duration of field-feeding time in the evening for those mallards which field-fed twice per day was 1.07±0.63 h and for those mallards which field-fed in the evening only was 0.84±0.57 h.

Figure 9. The observed temporal distribution for the duration of field-feeding of mallards in the evening for those which field-fed twice per day and those which field-fed in the evening only.



Two variables which relate to the morning field-feeding period, more specifically to the timing of the departure, account for 79.9% of the variance amongst those mallards that field-fed both in the morning and afternoon. This time difference between the morning departure and the evening arrival at a field-feeding site is possibly related to the "metabolic cue" proposed by Hochbaum (1955): "The ducks do not return to the fields while breakfast is still heavy in their gizzards; but once digestion has progressed to the point of hunger, this stimulus urges them to the prairie for a second meal". In this manner, the departure from a field-feeding site in the morning may influence the afternoon feeding period.

Unfortunately, the morning feeding activity of those mallards monitored in the evening only was not documented. In considering the two feeding periods of those mallards which fed in the morning and evening and those which were monitored in the evening only, it is apparent that the morning feeding behaviour must be documented, if any attempt is to be made in predicting the length of the evening field-feeding period.

Change in light intensity between arrival and departure contributes significantly to both groups of mallards although its contribution to the variance for those mallards field-feeding in the evening only is much greater (12.1% versus 54.7%). This is consistent with the data concerning arrival and departure where light intensity is the largest single contributing meteorological variable. Also, the correlation coefficient, r, between the duration of field-feeding and the change in light intensity for those birds that field-fed only in the evening r = 0.740 ($P<0.05$), and for those birds that fed twice per day r = 0.758 ($P<0.05$) are approximately equal. This indicates that within the two samples the singular effect of change in light intensity upon field-feeding duration was approximately the same.

VII. The Importance of Light to Field-feeding

The field-feeding patterns of the mallard in the present study were bimodal with peak activity occurring in the morning and evening. This agrees with the activity patterns established by Winner (1972). If this pattern is endogenous as suggested by Winner (1972) then it may be a true circadian rhythm. Under natural environmental conditions there must be some periodic factor to which the circadian rhythm can be entrained (Aschoff 1966).

Light intensity (the log of the absolute values in lux units) explains a significant amount of the variance in field-feeding. The largest effect is associated with arrival in both the morning and evening and the departure in the evening. Under total darkness no field-feeding occurred. The amount of available light may be the periodic environmental cue to which the circadian rhythm could be entrained.

Current physiological research also indicates that the light-dark cycle experienced by animals in the natural environment has a significant affect on the circadian rhythm. Binkley (1976) suggested that the light-dark cycle affects the N-acetyltransferase enzyme activity of the pineal gland which has a hormonal output melatonin. The circulating levels of melatonin could act as the "fundamental pacemaker". The different levels act as "a time cue by other cells for synchrony or generation of their own rhythms", (Binkley 1976). Furthermore, Binkley (1979) suggested that this mechanism can be reset by the light cue corresponding to dark. This allows the bird to measure the daylight length or the process of photoperiodism.

# SUMMARY AND CONCLUSION

The study was conducted to determine if meteorlogical factors had any significant effect upon the daily field-feeding behaviour of post-moult adult male and female mallard ducks. In addition, differences due to sex and differences among those mallards that were recorded field-feeding twice per day (morning and evening) and once per day (morning or evening only) were examined. The influence of the morning field-feeding period or the evening field-feeding period within those mallards that field-fed twice per day was investigated.

Sixteen adult male and eight adult female mallards were equipped with ratio transmitters (6 males and 4 females in 1977; 10 males and 4 females in 1978). This allowed for the signal recognition of each individual bird while monitoring its movement between the marsh and a field-feeding site. For statistical analysis an observation consisted of the single recording of a radio-equipped mallard at a field-feeding site either in the morning or afternoon on a particular day. Data were pooled for 1977 and 1978, because daily effects, not annual effects, were being examined. A unique set of meteorological data was collected for each observation.

The data suggest the following observations and conclusions:

1. Although individual mallards were not observed in the field, the behavioural changes caused by the radio packages were considered to be minimal, 88% of the mallards initiated field-feeding within the normal adjustment period of two weeks as suggested by the literature. The larger and heavier SB-2

transmitter had an apparent greater physical effect on the mallards than the smaller and lighter SM-1 radio package.

2. Mallards preferred swathed barley and wheat although they would feed on stubble. Some mallards flew at least 23 km from the marsh to feed on a swathed wheat crop.
3. Field-feeding was restricted primarily to two periods, early morning and in the evening.
4. Considering those days when a field-feeding site was monitored in both the morning and evening, there appeared to be no set pattern to the appearance of a mallard in both the morning and evening. Some mallards field-fed in both the morning and evening while others field-fed in the morning only or evening only.
5. There was no significant difference in field-feeding activity between adult male and adult female mallards.
6. Light intensity was the main meteorological factor governing the arrival and departure times from a field-feeding site. This is consistent with other avian related behavioural and physiological studies which suggest light may be the environment cue by which the bird's normal circadian activity is entrained.
7. The presence of cloud cover during rainy periods significantly delayed the arrival at a field-feeding site.
8. Rain significantly delayed the departure and therefore lengthened the period of stay at a field-feeding site.

9. The length of time a mallard remained at a field-feeding site in the morning was altered by the departure time not the arrival time.

10. The time a mallard spent away from a field-feeding site, between the morning departure from the site and the evening arrival, contributed significantly to the duration of field-feeding time in the evening. This is most probably related to the stimulus, provided by hunger, to field-feed in the evening (Hochbaum, 1955).

11. The length of a time a mallard remained at a field-feeding site in the evening was governed by the arrival time, not the departure time.

12. Mallards were never recorded feeding during the night although evening field-feeding extended into darkness (no measurable light) on several occasions; they remained only several minutes.

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# APPENDIX A

# EQUIPMENT

## Appendix A1

### Transmitter Packages

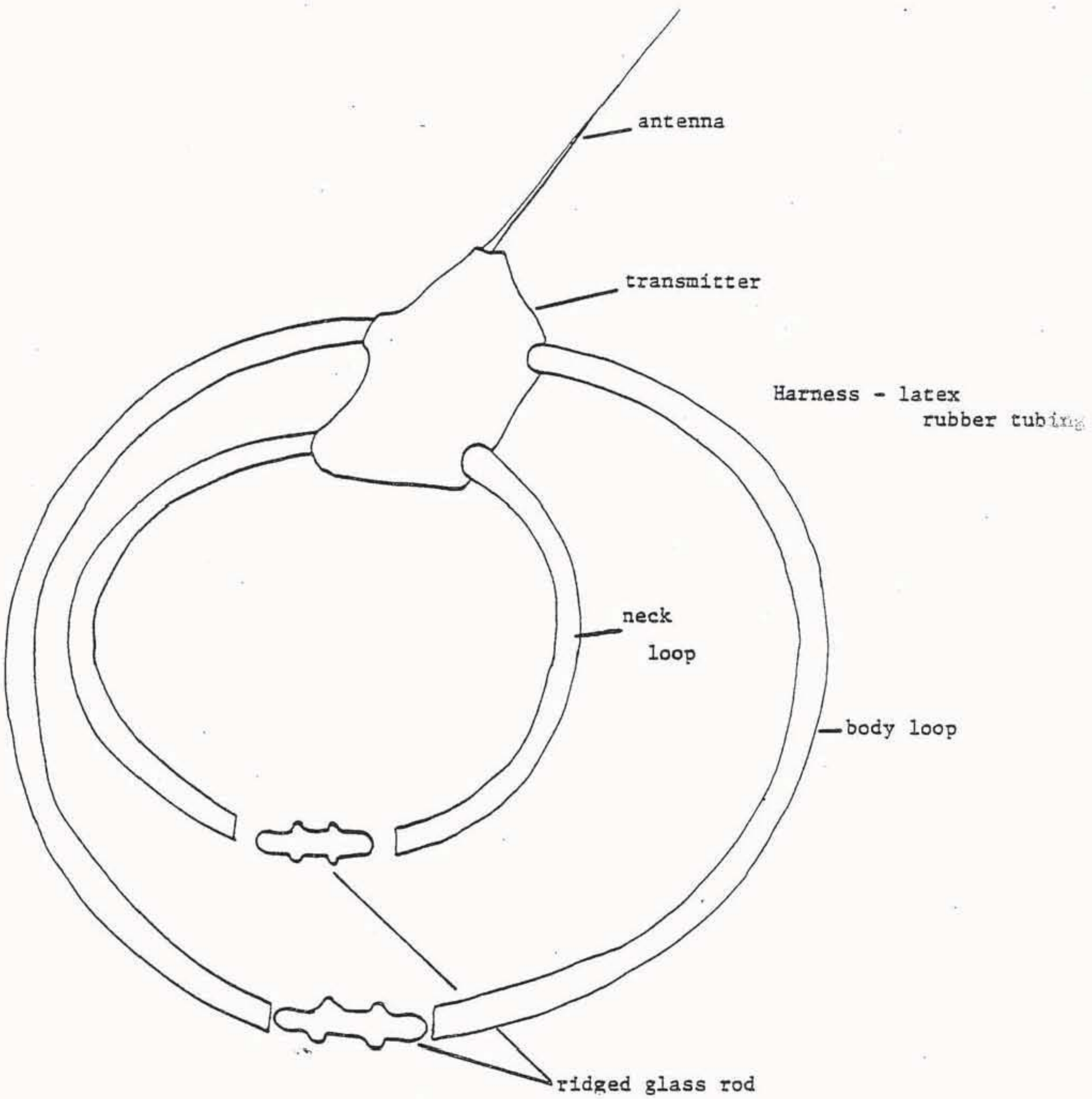
All the SM-1 radio packages (Fig. A1-1) were constructed in the same manner. Heat shrinkable tubing (length 12 cm) was threaded over the antenna wire and positioned at its base to help prevent moisture from collecting at the base of the antenna, thereby preventing corrosion and premature breaking of the antenna. Strength at the antenna base was also increased.

The encapsulating material was a mixture of Elvas 260 vinyl resin and sealing wax (Dupont 1966, Goodman and Gibson 1970) mixed in a 1 to 1 ratio (personal comminication - Fred Anderka, Bioelectronics Technician C.W.S.). Both compounds were placed in a beaker and heated. Melting occurred at about 80°C. The mixture was stirred and placed in a vacuum oven for 12 h to remove any air bubbles. The material in the liquid state was extremely viscous and this facilitated molding into the desired shape.

One piece of vinyl tubing, approximately 6 mm inside diameter (I.D.), by 20 mm in length was placed at each end of the radio package and secured in place with the encapsulating compound, thereby providing attachment for the harness.

The SM-1 transmitter was powered by one 1.35 volt battery, Mallory

Figure A1-1. SM1 Transmitter package



model MP 675. Life expectancy varied due to the different current drain of each transmitter. Theoretical maximum transmitting life expectancies were 89 days (5 units), 100 days (3 units), 114 days (13 units) and 133 days (1 unit). Weight of the assembled packages was between 10.1 g and 13.7 g. The rubber harness weighed an additional 7.3 to 8.3 grams.

Two SB-2 transmitters (AVM Instrument Company) were used. Antenna, battery connections, and single strand thin copper capacitor wire were attached, as per instructions from AVM Instrument Company Telemetry Manual (1974). Two 1.35 volt batteries, Mallory model MP 630, were connected in series to equal a 2.70 volt output required by the SB-2 transmitter. Theoretical life expectancy of the transmitter packages were 45 days each. Encapsulating material was the same used for the SM-1 units. The weights of the packages were 33.4 and 32.4 grams with an additional harness weight of 7.3 to 8.3 grams each.

Radio package malfunction, alteration in frequency or pulse rate or termination of the signal, were associated with either the transmitter or batteries. Transmitters were field tested as to factory specialized frequency, pulse rate and current draw. Battery voltage was checked. Batteries were also x-rayed to determine manufacturing flaws and partially spent batteries (Harding et al. 1976). X-ray photography was done by Mr. Giardino at the Manitoba Agricultural Services Complex. Mallory MP 675 batteries were x-rayed and photographs were bracketed as to suggested voltages and exposures. Results were inconclusive and the test was of no value. Transmitters were activated several days before being attached to a mallard to assure at least initial transmitting success.

The harness material was pure latex (amber) 3.2 mm I.D. by 4.8 mm outside diameter (O.D.). The capacitor wire was threaded into the tubing. Two harness loops were used (Dwyer 1972). The loop ends were secured to each other with ridged glass rods approximately 25 mm in length prepared from 3 mm I.D., 5 mm O.D. glass tubing.

The harness was made of pure latex rubber tubing (amber) versus vinyl tubing because of its elasticity. This was necessary because of a significant loss of pectoral muscle mass during the flightless period (Young 1977). The harness had to allow for the increase in body circumference due to increased pectoral mass in the time following the flightless period (Young 1977) and the subsequent increase in body weight (Owen and Cook 1977; Folk et al. 1966). This increase in body weight was due mainly to an increase in the amount of body fat (Street 1975).

# Appendix A2

## Stationary Towers

Three different tower structures were used with the antenna systems:

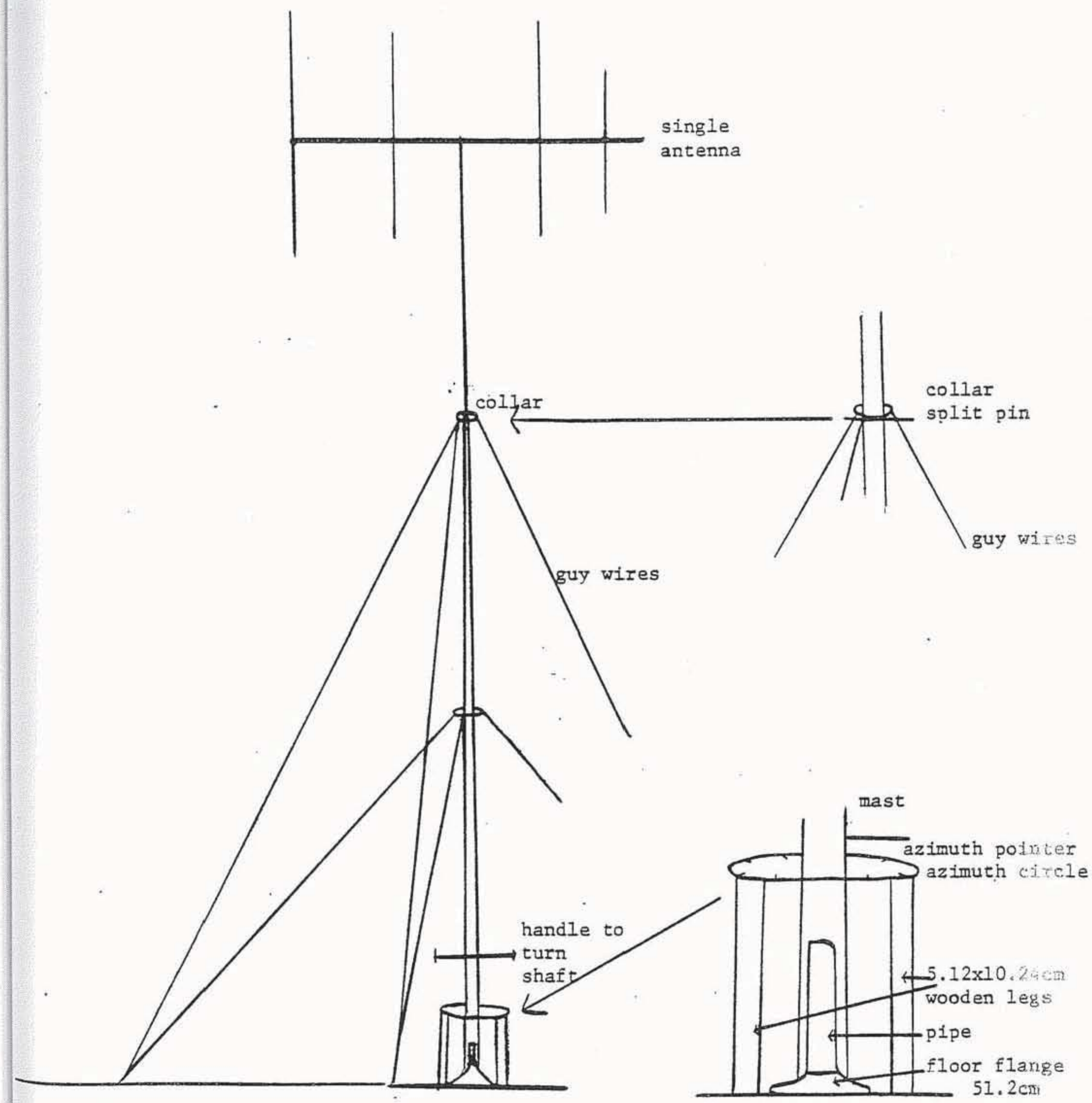
1. 9.14 m (30 ft) Delhi Pop-Up Towers Model No. 30A were used to support the 11 element antenna,
2. 12.19 m (40 ft) Delhi Pop-Up Towers Model No. 40A were used to support the 4 element antenna, and
3. 15.85 m (52 ft) Delhi Self-Supporting DMX Series Concrete Base Towers Model No. DMX-52 were used to support the null-peak antenna systems.

The tower mounted antenna increased the receiving range between the receiving and transmitting locations (AVM Instrument Company Manual 1974).

In 1977, 9.14 m and 12.19 m pop-up masts (Fig. A2-1) were used. The masts were supported by guy wires anchored to metal stakes in the ground and attached to the collars on the masts. An azimuth circle was located at the base of the tower, with the mast shaft passing through the centre of the azimuth circle. A pointer was attached to the shaft such that the antenna and pointer moved together. These towers had problems associated with their structure:

1. The collars to which the guy wires were attached would lock on to the tower shaft, thereby preventing rotation. Therefore, the point where the collars rotated was modified. A hole was drilled and a 4.8 mm split pin was inserted such that the collar rested on the split pin. The area was generously lubricated with grease.

Figure A2-1. Schematic diagram of the pop-up mast.



2. The guy wires were not taut, therefore, the masts bent in high winds. This eventually produced a permanent bow in the mast. Therefore, when the mast was rotated, the pointer did not follow a circular path on the azimuth circle.
3. The 12.19 m mast would only support the 4 element antenna. The 9.14 m mast would support either the 4 element or 11 element antenna. Neither would support a null-peak antenna system due to the excess weight.
4. The mast could not be rotated repeatedly in one direction through $360^{\circ}$ arcs because antenna lead movement was restricted by the guy wires. Therefore, it became necessary to rotate the mast in one direction and then in the other.

Due to the latter three problems, a modified self-supporting tower, Delhi DMX 52 was used in 1978 (Fig. A2-2 and 3). A shaft made up of five 18 gauge 31.75 mm O.D., 3.05 m lengths of swedged mast tubing bolted together and supported by 3 Delhi Model BBMB sealed bearings was centered within the superstructure of the tower. The bearing had sufficient inside diameter of 50.8 mm to allow the shaft and 2 antenna leads to pass through it. The shaft was supported securely by the bearings and therefore turned easily at the base and could support a null-peak system. Windy conditions had no adverse effect on the function of the unit.

Figure A2-2. Modified DMX-52 tower.

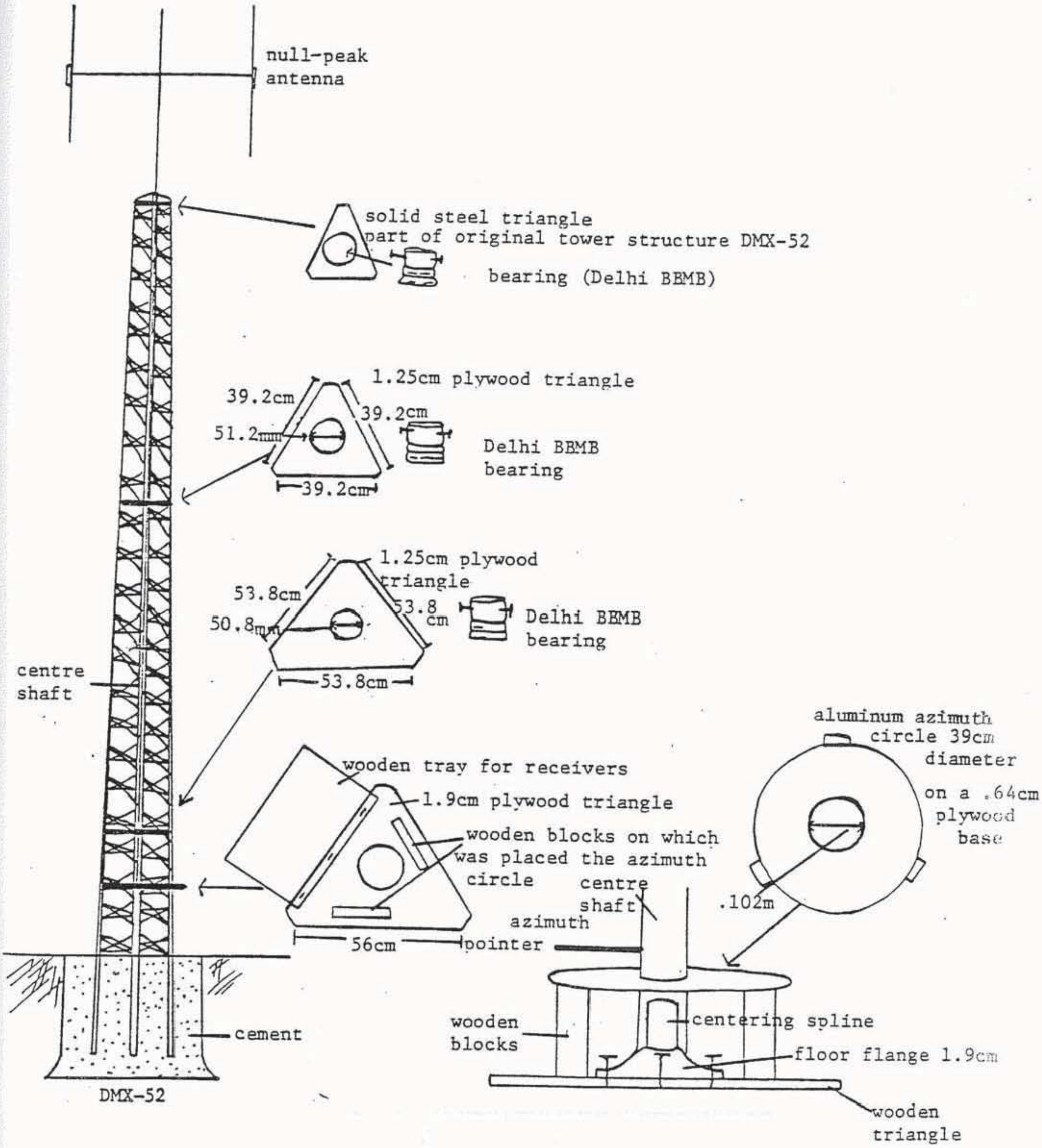
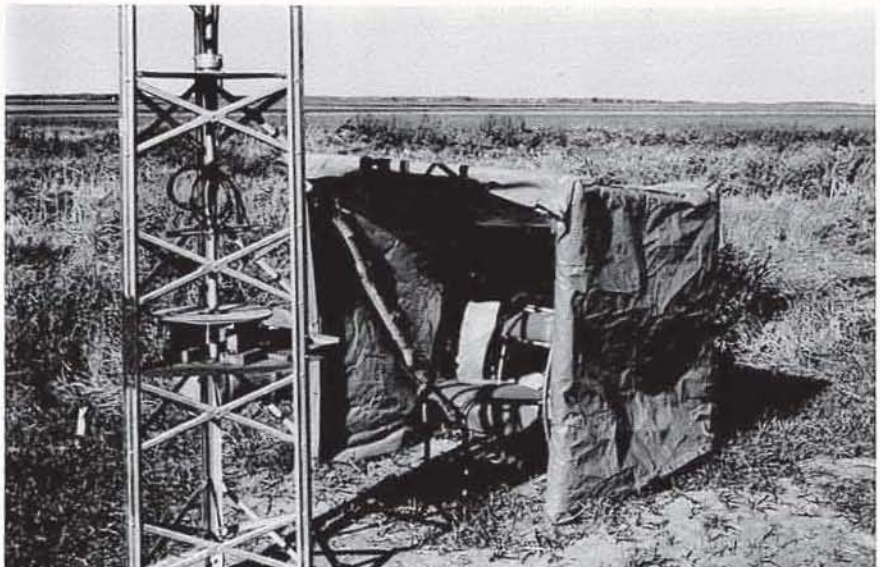


Figure A2-3. Pictures of the modified DMX-52 tower.



## Appendix A3

### Mobile antenna masts.

Two mobile null-peak antenna systems were constructed. The first unit (Fig. A3-1 and 2) was used in 1977 and during part of 1978. The antenna was used only when the vehicle was in a stationary position. The mast was on a hinged wooden plate in the truck box and was raised or lowered manually (Fig. A3-3). When the vehicle was moving, the antenna was in the horizontal position. In the vertical position, the antenna was approximately 3.8 m above the ground. The operator manually turned the mast. This unit was equipped with a null-peak antenna.

The second unit was a completely mobile unit (Fig. A3-4 and 5), used only in 1978. It had been time consuming to stop and to raise and lower the first unit described. Therefore, an antenna system that was fully operable while the vehicle was in motion was constructed. This was accomplished by having the antenna mast extending through the cab roof of the vehicle, thus enabling the vehicle driver or second party in the truck to turn the mast from within the cab. A null-peak antenna system was used. The mast was made of 25.4 mm (1 in) superior shafting (Pritchard Engineering, Winnipeg, Manitoba). Three self-aligning 25.4 mm bearings were used on the shaft, two of these were for supportive purposes and the third had an azimuth circle secured to it. One bearing was located on the roof of the cab and the second was located on the floor of the cab. The mast was solid steel, therefore, two grooves were cut in the shaft at the point where it passed through the cab roof bearing to allow the antenna leads to enter the cab. A plywood plate

Figure A3-1. Mobile tower (1977).

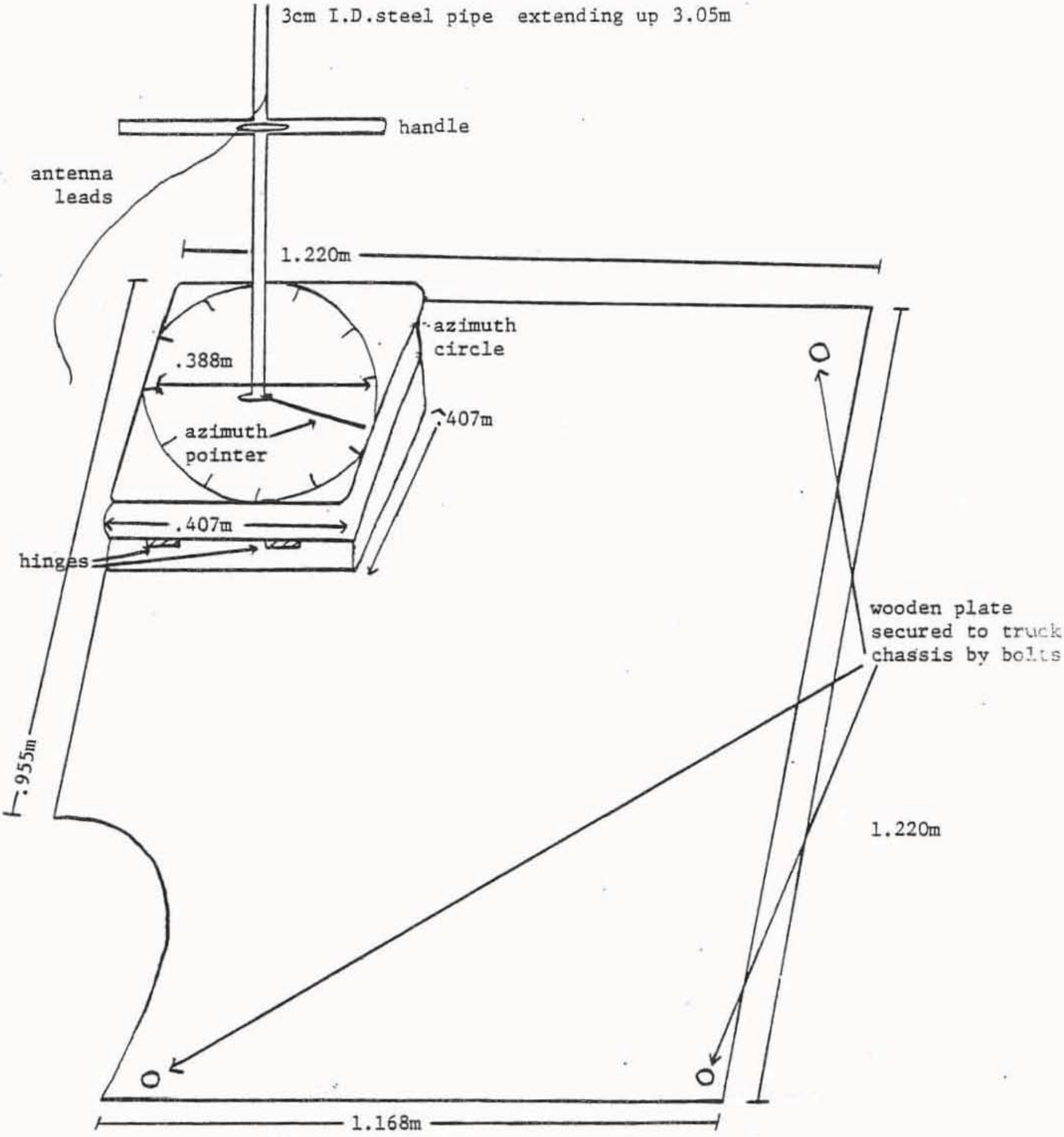


Figure A3-2. Pictures of the mobile tower (1977) in operating position.

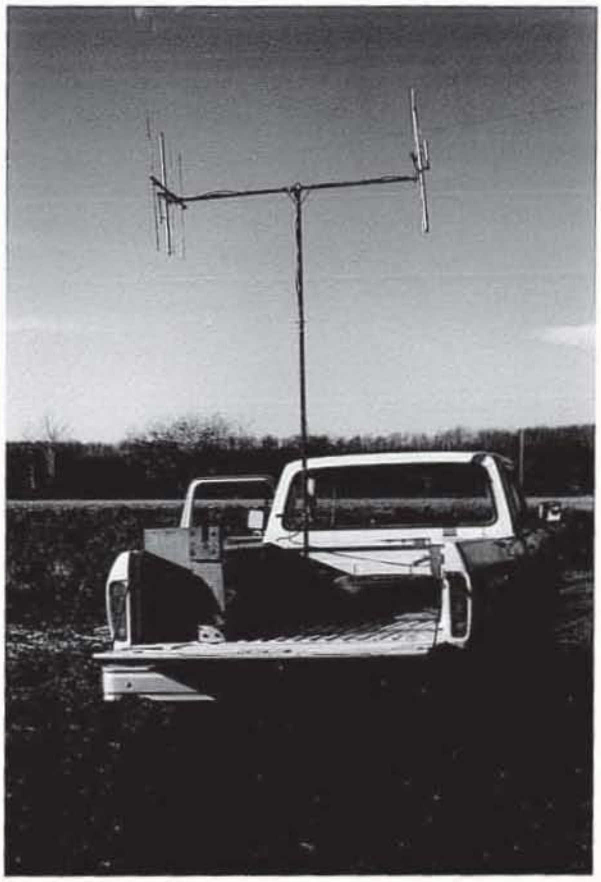


Figure A3-3. Pictures of the mobile tower (1977) in transporting position.

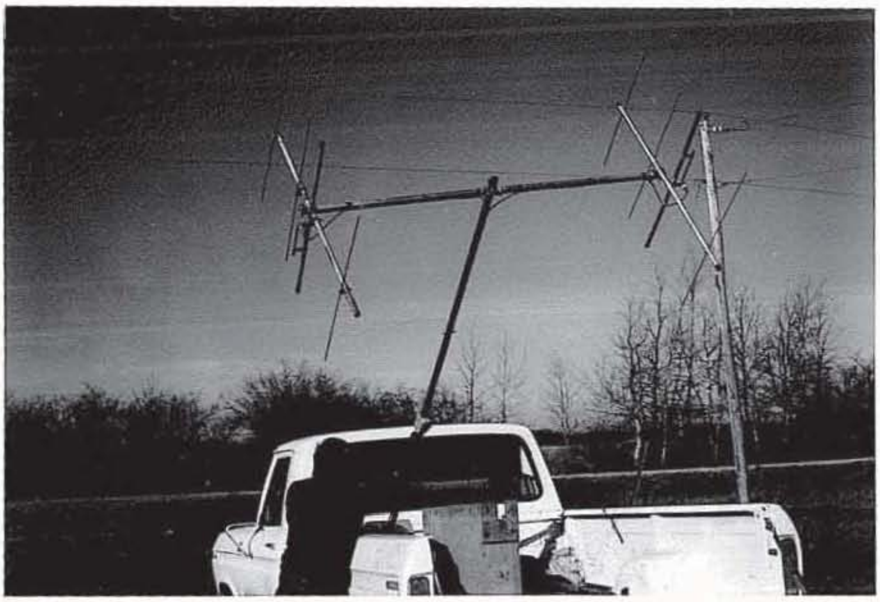


Figure A3-4. Schematic diagram of the 1978 mobile tower.

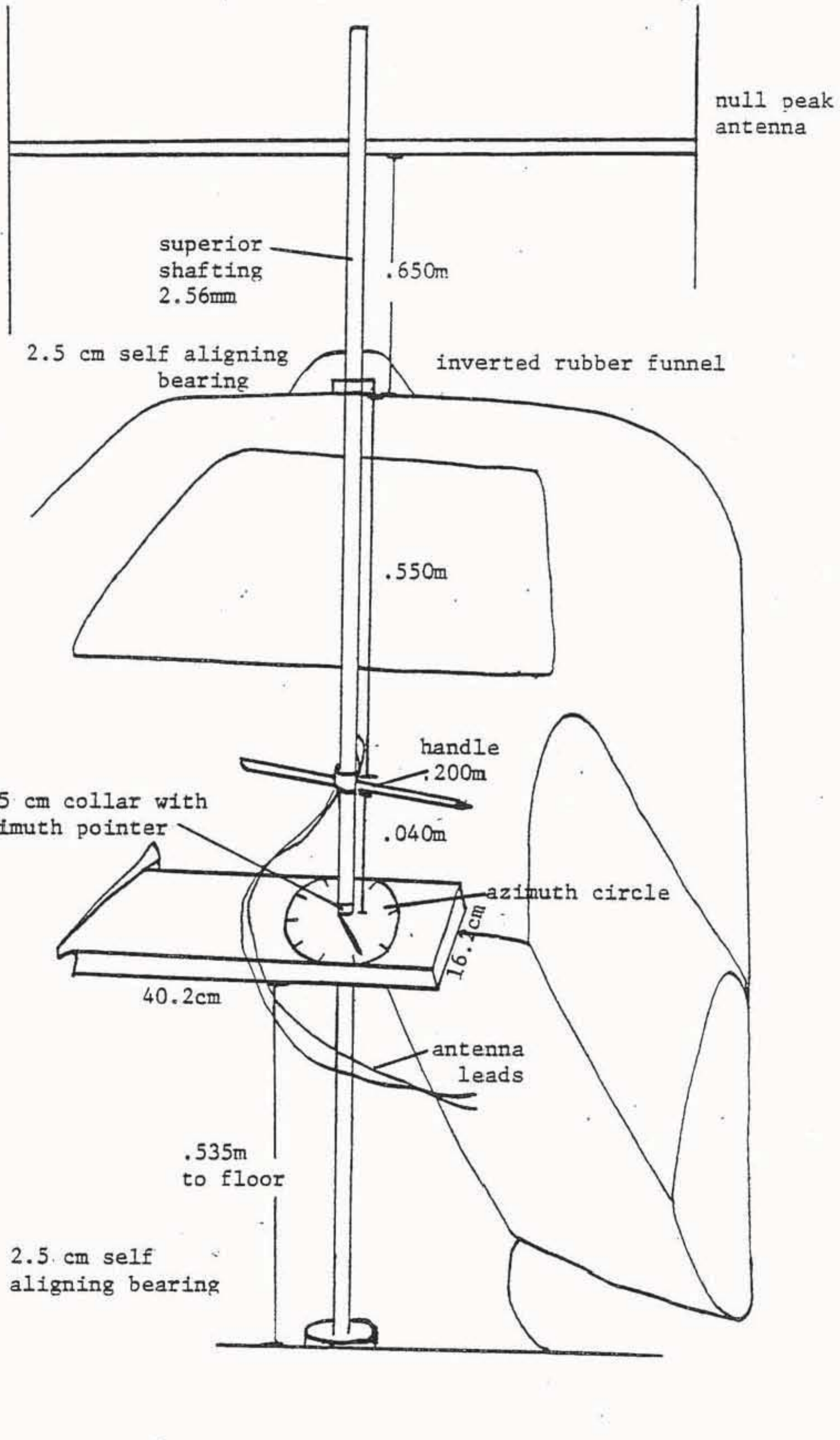
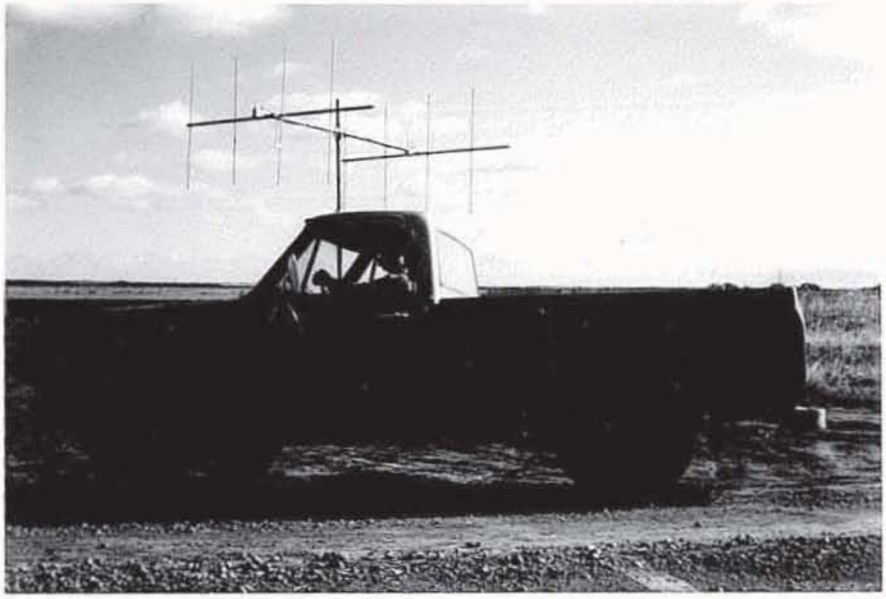


Figure A3-5. Pictures of the 1978 mobile tower.



was positioned so that one end of it rested in the dash where the vehicle radio was supposed to be and the other end was secured to the third bearing. The azimuth circle was secured to this wooden plate. An azimuth pointer was soldered onto a 25.4 mm collar which was secured to the shaft, above the azimuth circle. The mast was oriented perpendicular to the horizontal axis of the truck. The twin antennae were secured to the top of the mast so that when the vehicle was in motion, the antenna array was always oriented in the direction the vehicle was travelling. Autorotation of the mast did not occur. The antennae were 2.2 meters above the ground.

# Appendix B

## Regression Analysis

Definitions of variables used in regression analysis.

| | |
|---|---|
| Light intensity | - Is the incident light measurement on a scale of 0-22 (Appendix B ) minimum to maximum light intensity. |
| Relative humidity | - Is the ratio of the amount of water vapour present in a fixed volume of air to the amount that could be held by the volume of air if it was saturated. |
| Temperature | - Air temperature in degrees celcius (°C). |
| Low temperature | - Lowest air temperature (°C) at night. |
| High temperature | - Highest air temperature (°C) during the midday. |
| Cloud cover | - The amount of cloud covering the sky from horizon to horizon. |
| Wind speed | - Velocity of wind in kilometers per hour. |
| Wind direction | - Measured in degrees of the compass. |
| Barometric pressure | - Measured in kilopascals (kpa). |
| Baroslope | - The slope of the barometric pressure prior to the monitored field-feeding period. |
| Sex | - Is the sex of the mallard denoted by the dummy variables 0 = male and 1 = female. |
| Bird | - Is a dummy variable for each mallard designated by the last two digits of the U.S. Fish and Wildlife leg band. |
| Weight of bird | - Is the weight in grams of each mallard at the time it was radio-equipped. |

Table B1. The light intensity on a scale of (0-22) converted to lux units by log transformation.

| Light units[1] | Lux units[2] | Log of lux units |
|---|---|---|
| 0 | 0.00 | 0.0 |
| 1 | 0.17 | -0.7695 |
| 2 | 0.35 | -0.4559 |
| 3 | 0.7 | -0.1549 |
| 4 | 1.4 | 0.1461 |
| 5 | 2.8 | 0.4472 |
| 6 | 5.5 | 0.7404 |
| 7 | 11.0 | 1.0414 |
| 8 | 22 | 1.3424 |
| 9 | 44 | 1.6434 |
| 10 | 88 | 1.9444 |
| 11 | 175 | 2.2430 |
| 12 | 350 | 2.5441 |
| 13 | 700 | 2.8451 |
| 14 | 1400 | 3.1461 |
| 15 | 2800 | 3.4472 |
| 16 | 5500 | 3.7404 |
| 17 | 11,000 | 4.0414 |
| 18 | 22,000 | 4.3424 |
| 19 | 44,000 | 4.6434 |
| 20 | 88,000 | 4.9445 |
| 21 | 175,000 | 5.2430 |
| 22 | 350,000 | 5.5440 |

[1]Denotes light unit scale from Grossen Lunasix 3 Light Meter.

[2]Denotes lux unit equivalent for each light unit equivalent.

Table B2. Summary of the regression analysis of all variables concerning mallards arrival at a field-feeding site in the morning during periods of no rain.

Dependent Variable - Arrival at a field-feeding site

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Light Intensity[1] | 0.85812 | 0.73638 | 0.73638 | 0.0686759 | 247.095 |
| Relative Humidity[1] | 0.93097 | 0.86670 | 0.13032 | -0.0865998 | 118.155 |
| Cloud Cover[1] | 0.93756 | 0.87902 | 0.01232 | 0.0142760 | 7.692 |
| Temperature[1] | 0.94507 | 0.89316 | 0.01415 | -0.0881431 | 37.387 |
| Low Temperature | 0.95712 | 0.91608 | 0.02292 | 0.0963785 | 29.758 |
| Wind Speed[1] | 0.96722 | 0.93551 | 0.01943 | 0.0113761 | 6.823 |
| Barometric Pressure[1] | 0.97056 | 0.94199 | 0.00648 | 0.0187994 | 4.336 |
| Sex | 0.97154 | 0.94390 | 0.00191 | 0.0820984 | 2.933 |
| Bird | 0.97219 | 0.94515 | 0.00126 | -0.0056988 | 1.145 |
| Wind Direction[1] | 0.97290 | 0.94654 | 0.00138 | -0.0001624 | 0.890 |
| Baroslope | 0.97297 | 0.94667 | 0.00014 | -0.0179703 | 0.099 |
| (Constant) | | | | -9.934253 | |

Equation: SE = 0.08869

F = 62.937

df = 40

[1]Recorded at the time of arrival at a field-feeding site.

Table B3. Summary of the regression analysis of all variables concerning mallards arrival at a field-feeding site in the morning during periods of rain.

Dependent Variable - Arrival at a field-feeding site

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | | F value |
|---|---|---|---|---|---|
| Light Intensity[1] | 0.84287 | 0.71042 | 0.71042 | 0.1543838 | 35.145 |
| Sex | 0.86557 | 0.74922 | 0.03879 | -0.2720232 | 2.015 |
| Wind Direction[1] | 0.87087 | 0.75842 | 0.00920 | -0.0019767 | 5.342 |
| Temperature[1] | 0.87828 | 0.77138 | 0.01296 | -0.1967393 | 4.410 |
| Low Temperature | 0.88975 | 0.79166 | 0.02028 | 0.1324702 | 3.381 |
| Bird | 0.89438 | 0.79992 | 0.00826 | 0.0236545 | 1.244 |
| Wind Speed[1] | 0.89933 | 0.80879 | 0.00887 | 0.0245270 | 1.403 |
| Baroslope | 0.90295 | 0.81532 | 0.00653 | 0.2532093 | 0.601 |
| (Constant) | | | | -0.7881774 | |

Equation: SE = 0.272

F = 9.381

df = 25

NOTE: The relative humidity[1], barometric pressure[1], and cloud cover[1] failed to meet inclusion criteria.

[1]Recorded at the time of arrival at a field-feeding site.

Table B4. Summary of the regression analysis of all variables concerning mallards departure from a field-feeding site in the morning during periods of no rain.

Dependent Variable - Departure from a field-feeding site

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Light Intensity[1] | 0.42775 | 0.18297 | 0.18297 | 0.0430616 | 2.765 |
| Temperature[1] | 0.57564 | 0.33196 | 0.14839 | 0.1228615 | 17.317 |
| Cloud Cover[1] | 0.64081 | 0.41063 | 0.07927 | 0.0821743 | 23.469 |
| Low Temperature | 0.74238 | 0.55113 | 0.14050 | -0.1184172 | 6.748 |
| Relative Humidity[1] | 0.78136 | 0.61052 | 0.05939 | -0.0158590 | 3.613 |
| Wind Direction | 0.80070 | 0.64112 | 0.03060 | -0.0007489 | 1.629 |
| Baroslope | 0.81174 | 0.65891 | 0.01780 | 0.3227135 | 2.470 |
| Barometric Pressure | 0.81936 | 0.66318 | 0.00426 | -0.0260238 | 0.752 |
| Sex | 0.81584 | 0.66560 | 0.00242 | -0.1353724 | 0.968 |
| Bird | 0.81978 | 0.67204 | 0.00644 | -0.0125329 | 0.740 |
| Wind Speed[1] | 0.82002 | 0.67243 | 0.00038 | 0.0027077 | 0.043 |
| (Constant) | | | | 25.45411 | |

Equation: SE = 0.24808

F = 6.905

df = 48

[1]Recorded at the time of departure from a field-feeding site.

Table B5. Summary of the regression analysis of all variables concerning mallards departure from a field-feeding site in the morning during periods of rain.

Dependent Variable - Departure from a field-feeding site

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Light Intensity[1] | 0.90065 | 0.81117 | 0.81117 | 0.5730898 | 76.699 |
| Wind Speed[1] | 0.96635 | 0.93382 | 0.12266 | 0.0289274 | 15.523 |
| Bird | 0.97502 | 0.95066 | 0.01683 | 0.0366526 | 5.041 |
| Sex | 0.97862 | 0.95770 | 0.00705 | -0.2556454 | 3.046 |
| Wind Direction[1] | 0.98043 | 0.96125 | 0.00354 | -0.0018402 | 2.426 |
| Temperature[1] | 0.98317 | 0.96662 | 0.00537 | -0.0528811 | 1.010 |
| Low Temperature | 0.98380 | 0.96785 | 0.00124 | -0.0286104 | 0.385 |
| (Constant) | | | | -6.542290 | |

Equation: SE = 0.184
F = 43.011
df = 17

NOTE: The baroslope, barometric pressure[1], cloud cover[1], and relative humidity[1] failed to meet inclusion criteria.

[1]Recorded at time of departure from a field-feeding site.

Table B6. Summary of the regression analysis of all variables concerning the duration of stay of mallards at a field-feeding site in the morning during periods of no rain.

Dependent Variable - Duration of time field-feeding

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Change in Light Intensity[1] | 0.68000 | 0.46241 | 0.46241 | -0.0764015 | 41.737 |
| Low Temperature | 0.70755 | 0.50062 | 0.03822 | 0.0237773 | 3.294 |
| Change in Relative Humidity[1] | 0.74898 | 0.56097 | 0.06035 | 0.0048473 | 0.474 |
| Weight of Mallard[2] | 0.76802 | 0.58986 | 0.02889 | 0.0012985 | 1.758 |
| Baroslope | 0.78137 | 0.61053 | 0.02067 | -0.6580598 | 10.412 |
| Change in Cloud Cover[1] | 0.80149 | 0.64238 | 0.03185 | 0.0571821 | 3.303 |
| Change in Barometric Pressure[1] | 0.82669 | 0.68342 | 0.04105 | -0.2000080 | 5.418 |
| Change in Temperature[1] | 0.83300 | 0.69389 | 0.01046 | -0.0337201 | 1.394 |
| Sex | 0.83348 | 0.69468 | 0.00079 | -0.0743273 | 0.224 |
| Bird | 0.83408 | 0.69569 | 0.00101 | 0.0056132 | 0.130 |
| (Constant) | | | | -1.329750 | |

Equation: SE = 0.272

F = 8.916

df = 49

[1]Change equals variable at arrival minus variable at departure.

[2]Weight at radio-equipping.

Table B7. Summary of the regression analysis of all variables concerning the duration of stay of mallards at a field-feeding site in the morning during periods of rain.

Dependent Variables - Duration of time field-feeding

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Baroslope | 0.65952 | 0.43497 | 0.43497 | -0.7979781 | 5.039 |
| Change in Temperature[1] | 0.80787 | 0.65265 | 0.21768 | 0.1983507 | 4.088 |
| Change in Light Intensity[1] | 0.90169 | 0.81304 | 0.16039 | -0.1233299 | 17.337 |
| Low Temperature | 0.95336 | 0.90890 | 0.09586 | 0.0871446 | 11.201 |
| Change in Barometric Pressure[1] | 0.96089 | 0.92331 | 0.01441 | 0.2958926 | 0.891 |
| Weight of Birds | 0.96110 | 0.92372 | 0.00042 | 0.0003810 | 0.057 |
| Bird | 0.96118 | 0.92386 | 0.00014 | -0.0030861 | 0.018 |
| (Constant) | | | | -0.4810532 | |

Equation: SE = 0.287
F = 17.333
df = 17

NOTE: Sex, change in cloud cover[1] and change in humidity[1] did not meet inclusion criteria.

[1] Change equals variable at arrival minus variable at departure.

[2] Weight at radio equipping.

Table B8. Summary of the regression analysis of all variables concerning the arrival of mallards at a field-feeding site in the evening for those mallards that field-fed twice per day.

Dependent Variable - Arrival at a field-feeding site

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ( $R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Light Intensity[1] | 0.89652 | 0.80375 | 0.80375 | 0.0665765 | 23.555 |
| Cloud Cover[1] | 0.93593 | 0.87596 | 0.07222 | 0.0148357 | 3.024 |
| On Marsh[2] | 0.95289 | 0.90801 | 0.03204 | -0.3286741 | 9.580 |
| Morning Departure From Field-feeding | 0.96741 | 0.9358 | 0.02787 | -0.2374818 | 4.373 |
| High Temperature | 0.97212 | 0.94502 | 0.00915 | -0.0345843 | 15.977 |
| Temperature[1] | 0.97514 | 0.95091 | 0.00588 | 0.0603451 | 16.163 |
| Relative Humidity[1] | 0.97743 | 0.95537 | 0.00447 | 0.0083228 | 5.549 |
| Barometric Pressure[1] | 0.98181 | 0.96395 | 0.00858 | 0.0279780 | 9.675 |
| Sex | 0.98269 | 0.96568 | 0.00173 | -0.1212289 | 3.868 |
| Bird | 0.98374 | 0.96775 | 0.00206 | 0.01131768 | 2.875 |
| Wind Speed[1] | 0.98421 | 0.96866 | 0.00092 | 0.00226084 | 0.200 |
| Duration of Morning Field-Feeding Period | 0.98448 | 0.96920 | 0.00054 | 0.0388956 | 0.479 |
| Wind Direction[1] | 0.98450 | 0.96925 | 0.00004 | 0.0000769 | 0.112 |
| Baroslope | 0.98455 | 0.96934 | 0.00010 | 0.0358446 | 0.091 |
| (Constant) | | | | -23.77305 | |

Equation: SE = 0.106; F = 65.495; df = 43

[1] Recorded at time of arrival at a field-feeding site.

[2] On marsh equals arrival time in the evening field-feeding period minus departure time in the morning field-feeding period.

Table B9. Summary of the regression analysis of all variables concerning the arrival of mallards at a field-feeding site in the evening for those mallards that field-fed in the evening only.

Dependent Variable - Arrival at a field-feeding site

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Light Intensity[1] | 0.79319 | 0.62915 | 0.62915 | 0.0860581 | 65.898 |
| Wind Speed[1] | 0.92350 | 0.85285 | 0.22370 | 0.0461587 | 7.740 |
| Sex | 0.94378 | 0.89072 | 0.03787 | 0.2793347 | 6.466 |
| High Temperature | 0.95569 | 0.91334 | 0.02262 | 0.0443505 | 8.365 |
| Baroslope | 0.96612 | 0.93339 | 0.02005 | 0.5141192 | 12.806 |
| Wind Direction[1] | 0.97724 | 0.95500 | 0.02160 | -0.0041268 | 20.987 |
| Temperature[1] | 0.99049 | 0.98106 | 0.02606 | -0.0838125 | 35.494 |
| Bird | 0.99436 | 0.98674 | 0.00768 | 0.0483173 | 14.672 |
| Relative Humidity[1] | 0.99801 | 0.99603 | 0.00728 | -0.0265670 | 8.763 |
| Cloud Cover[1] | 0.99943 | 0.99886 | 0.00284 | -0.0552119 | 2.502 |
| (Constant) | | | | 1.584711 | |

Equation: SE = 0.050
F = 87.991
df = 11

NOTE: Barometric pressure[1] did not meet inclusion criteria.

[1]Recorded at time of arrival at a field-feeding site.

Table B10. Summary of the regression analysis of all variables concerning the departure from a field-feeding site for all mallards in the evening.

Dependent Variable - Departure from a field-feeding site

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ($\Delta R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Light Intensity[1] | 0.90358 | 0.81646 | 0.81646 | 0.0827056 | 149.301 |
| Wind Speed[1] | 0.92173 | 0.84951 | 0.03313 | 0.0080944 | 4.057 |
| Wind Direction[1] | 0.92780 | 0.86081 | 0.01122 | -0.0003729 | 3.222 |
| Bird | 0.92897 | 0.86299 | 0.00219 | -0.0072694 | 1.971 |
| Sex | 0.93152 | 0.86773 | 0.00474 | 0.0612179 | 1.421 |
| Barometric Pressure[1] | 0.93229 | 0.86916 | 0.00143 | -0.0030886 | 0.235 |
| Relative Humidity[1] | 0.93298 | 0.87045 | 0.00130 | -0.0042425 | 1.344 |
| Baroslope | 0.93379 | 0.87197 | 0.00151 | 0.0727438 | 0.578 |
| High Temperature | 0.93405 | 0.87244 | 0.00048 | 0.0049880 | 0.620 |
| Cloud Cover[1] | 0.93467 | 0.87362 | 0.00117 | 0.0047983 | 0.380 |
| Temperature[1] | 0.93499 | 0.87420 | 0.00059 | -0.0039551 | 0.192 |
| (Constant) | | | | 2.424951 | |

Equation: SE = 0.104

F = 25.902

df = 52

[1]Recorded at time of departure from a field-feeding site.

Table B11. Summary of the regression analysis of all variables concerning the duration of stay at a field-feeding site in the evening for those mallards which field-fed twice per day.

Dependent Variable - Duration of time field-feeding

| Independent variable | Multiple R | Multiple $R^2$ | Multiple $R^2$ change ( $R^2$) | Regression coefficients | F value |
|---|---|---|---|---|---|
| Change in Light Intensity[1] | 0.086405 | 0.74658 | 0.74658 | 0.0461244 | 48.216 |
| On Marsh[2] | 0.89972 | 0.80949 | 0.06291 | -0.4599027 | 99.309 |
| Morning Departure From Field-Feeding | 0.96196 | 0.92536 | 0.11587 | -0.5301399 | 38.536 |
| High Temperature | 0.96775 | 0.93653 | 0.01117 | -0.01481195 | 8.083 |
| Change in Temperature[1] | 0.97648 | 0.95351 | 0.01698 | 0.0928264 | 9.980 |
| Weight of Bird[3] | 0.97893 | 0.95830 | 0.00478 | 0.00127213 | 3.686 |
| Change in Relative Humidity[1] | 0.97972 | 0.95986 | 0.00156 | 0.0057427 | 1.597 |
| Sex | 0.98023 | 0.96086 | 0.00100 | 0.08606716 | 0.762 |
| Change in Barometric Pressure[1] | 0.98070 | 0.96177 | 0.00091 | 0.0507075 | 0.811 |
| Duration of Morning Field-Feeding Period | 0.98102 | 0.96241 | 0.00023 | 0.0427240 | 0.153 |
| Bird | 0.98103 | 0.96242 | 0.00002 | 0.0006576 | 0.013 |
| (Constant) | | | | 8.943205 | |

Equation: SE = 0.111; F = 59.763; df = 40

NOTE: Change in cloud cover[1] did not meet inclusion criteria.

[1]Change equals variable at arrival time minus variable at departure time.

[2]On marsh equal arrival time in the evening field-feeding period minus departure time in the morning field-feeding period.

[3]Weight at radio-equipping.