REPRODUCTIVE ECOLOGY OF THE PIPING PLOVER AT CHAPLIN LAKE, SASKATCHEWAN

Diane C. Martens[1,2]
J. Paul Goossen[1]

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[1]Canadian Wildlife Service, Environment Canada, Room 200, 4999-98 Avenue, Edmonton, Alberta T6B 2X3

[2]823-12th Street, Saskatoon, Saskatchewan S7N 0H6

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Canadian Wildlife Service
Environment Canada
Room 200, 4999-98 Avenue
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T8A 6C2

Top photo: Piping Plover chick at Chaplin Lake, Saskatchewan (Photo by Val Harris)

Middle photo: Banding a Piping Plover chick at Lake Diefenbaker, Saskatchewan (Photo by Renee Franken)

Bottom photo: Piping Plover chick with radio transmitter at Lake Diefenbaker, Saskatchewan (Photo by Tim Neumann)

ABSTRACT

Piping Plover (*Charadrius melodus*) population size, nesting chronology and productivity were monitored at Chaplin Lake, Saskatchewan during the 2005 breeding season. Two hundred Piping Plover adults were counted during a pair count on 30 and 31 May. The estimated number of breeding pairs in 2005 was 96. Clutch initiation spanned 61 days from 8 May to 7 July with a median initiation date of 21 May. Egg laying starts were least synchronous compared to those in the previous three years with a standard deviation of 13 days (n = 115) in 2005. In total, 123 nests and 11 broods without associated nests were located. The number of nests found in 2005 was 64-242% higher than the previous four years. Apparent nest success was 56% and Mayfield nest success was 38%. Most (69%) nest failures were attributed to predation. One hundred and eleven young (57%) were known to survive to 18 days of age for a fledging estimate of 1.16 young per pair, the highest recorded in four years at Chaplin Lake.

Radio transmitters were attached to 61 chicks to study survival, chick movement, growth and to assess observer detectability. Chicks were closely monitored until fledging, death, or loss of transmitter. Forty-five (74%) chicks were known to survive to 25 days of age. Of the chicks less than 18 days of age, seven of the 61 chicks were missing, two were found dead, and two were unable to be tracked. Of the chicks that reached 18 days of age, two were missing, five were found dead, and six were unable to be tracked. Chicks reached 60% of adult mass by 19 days of age, and began flying on average at 26 days. Some young (n = 8) remained on the lake for at least 50 days. Chicks under 10 days moved on average 137 m ± 89 m away from the nest. Apparent disparity in observed distances ($P > 0.05$) moved by chicks under 18 days of age from traditional (200 ± 127 m (n = 47)) and telemetry (270 ± 243 m (n = 35)) observations suggests researchers monitoring broods on alkali lakes may have to expand search areas to ensure fledging rates are accurate.

RÉSUMÉ

La taille de la population, la chronologie de reproduction et la productivité des pluviers siffleurs (*Charadrius melodus*) ont été évaluées au lac Chaplin, en Saskatchewan, au cours de la période de reproduction de 2005. Deux cents pluviers siffleurs ont été dénombrés au cours d'un recensement des couples effectué les 30 et 31 mai. En 2005, le nombre de couples reproducteurs a été estimé à 96. Le début de la période de couvée s'est étendue sur 61 jours, du 8 mai au 7 juillet, la date médiane de début étant le 21 mai. La ponte s'est faite de manière moins synchrone que lors des trois années précédentes, l'écart-type pour 2005 étant de 13 jours (n = 115). Au total, 123 nids et 11 couvées qui n'ont pu être associées à un nid ont été recensés. Le nombre de nids trouvés en 2005 était de 64 – ce qui est 242% plus élevé que les quatre années précédentes. Le taux de succès apparent de la nidification était de 56% et le taux de succès de la nidification selon la méthode de Mayfield était de 38 %. La majorité (69%) des échecs de nidification ont été attribués à la prédation. On sait que 111 petits (57%) étaient toujours vivants à 18 jours, ce qui permet d'estimer que 1,16 petit par couple a survécu jusqu'à la première envolée. Il s'agit du taux le plus élevé à avoir été enregistré au lac Chaplin depuis quatre ans.

On a attaché des émetteurs radio à 61 poussins afin d'étudier leur taux de survie, leurs déplacements et leur croissance, et afin d'évaluer la détectabilité des observateurs. Les poussins ont été suivis de près jusqu'à leur première envolée, leur décès ou la perte de l'émetteur. On sait que 45 poussins (74%) ont survécu jusqu'à l'âge de 25 jours. Des poussins de moins de 18 jours, 7 sur 61 manquaient à l'appel, 2 ont été trouvés morts et 2 n'ont pu être retracés. Des poussins qui ont atteint 18 jours, 2 manquaient à l'appel, 5 ont été trouvés morts et 6 n'ont pu être retracés. Les poussins ont atteint 60% de leur masse adulte à 19 jours et ont commencé à voler à 26 jours en moyenne. Certains petits (n = 8) sont demeurés sur le lac pendant au moins 50 jours. Les poussins de moins de 10 jours se sont éloignés du nid en moyenne de 137 m ± 89 m. Sur le plan des distances ($P > 0.05$) parcourues par les petits de moins de 18 jours, l'écart observé entre la méthode traditionnelle d'observation (200 ± 127 m (n = 47)) et la télémétrie (270 ± 243 m (n = 35)) laisse croire que les chercheurs qui surveillent les nichées des lacs alcalins pourraient

devoir étendre leurs zones de recherche pour s'assurer que les taux de succès d'envol sont exacts.

ACKNOWLEDGEMENTS

Immense thanks goes to the field crew of Kristin Alm, Val Harris, and David Johns. They worked many long days, often right until dark and provided great friendship while living in Chaplin. Thanks to the staff at Saskatchewan Minerals and at the Chaplin Nature Centre for sharing your knowledge of the lake and community. Your friendships were greatly appreciated. Special thanks to the landowners who granted access to the lake. Thanks to Cheri Gratto-Trevor (Canadian Wildlife Service, Saskatoon) and Corie White (Saskatchewan Watershed Authority, Regina) for all the plover discussions throughout the summer and for your sympathy and shared distain for alkali mud. We thank Cheri Gratto-Trevor, Sharilyn Westworth (Canadian Wildlife Service, Edmonton) and Corie White for their comments on the manuscript and Gillian Turney (Canadian Wildlife Service, Edmonton) for preparing the location map.

TABLE OF CONTENTS

List of Tables

List of Figures

Appendix list

1.0 Introduction

Piping Plover (*Charadrius melodus*) populations showed a decline in the early 1900s (Tyler 1929) and again in the 1940s (Tate 1981). Sufficient concern about this plover's future prompted the Committee on the Status of Endangered Wildlife in Canada to officially recognize the plover as a species at risk by listing it in 1978 as Threatened (Bell 1978). The plover's status in Canada was upgraded to Endangered in 1985 (Haig 1985). In 1986, the United States' Endangered (Great Lakes region) and Threatened (elsewhere) designations went into effect. In 2001, the two subspecies, *circumcinctus* (inland) and *melodus* (Atlantic coast) were separately listed as Endangered in Canada (COSEWIC 2001).

Recovery of the Northern Great Plains Piping Plover (*circumcinctus*) has considerable potential due to high concentrations of Piping Plover populations and relatively low levels of human disturbance (Prindiville Gaines and Ryan 1988). The Northern Great Plains provide habitat for 50 to 63% of the North American population and within this region, alkali lakes support 37 to 75% of the plovers (Haig and Plissner 1992, Plissner and Haig 1997, Ferland and Haig 2002). There is a continuing need to better understand Piping Plover breeding biology on Northern Great Plains alkali habitats so that management activities can be refined and productivity maximized.

Results from the 1991 (Haig and Plissner 1992), 1996 (Plissner and Haig 1997), and 2001 (Ferland and Haig 2002) International Piping Plover Breeding Censuses suggest a decline in the Northern Great Plains population. The most recent international census in 2006, however, shows that the Northern Great Plains population has increased. Low fledging success is considered one of the leading hypotheses explaining the decline or limitation of the Piping Plover; yet the accuracy of estimating fledging success remains a knowledge gap (Westworth et al. 2004). Individual and brood detectability influences census accuracies and brood counts. Recent modeling suggests that a median fledging rate of 1.25 fledged chicks per pair per year is needed to stabilize the Northern Great Plains population (Larson et al. 2000). Western populations rarely attain this level of fledging success

(Westworth et al. 2004). This appears to be the case as well at Chaplin Lake where fledging success from 2002 to 2004 averaged only 0.8 young fledged at 18 days per breeding pair per year (White 2004). Reasons for apparent low fledging success are not well understood. Estimating fledging success is confounded with determining the fate of chicks as they are small, well camouflaged, use vegetation to hide and are capable of moving long distances. The use of radio telemetry enables improved fate determination of chicks and therefore a more accurate fledging estimate.

The goals of this report, based on field data collected at Chaplin Lake, Saskatchewan in 2005, are to: (1) determine Piping Plover reproductive success (2) examine the accuracy of estimating fledging success and provide suggestions for improved data collection and analysis, (3) investigate the limitations of productivity by predation (4) document pre- and post-fledging movements of chicks and (5) examine chick growth. Previous fieldwork at Chaplin Lake, by the Saskatchewan Watershed Authority (SWA) and the University of Regina, included pair and brood surveys, determining annual productivity, nest and brood survival and identifying nest predators (White 2004, 2005).

2.0 Study area

Chaplin Lake (50º 22' N, 106º 36' W) is a large saline lake covering a glacial sodium sulfate deposit in the Missouri Coteau region. The lake is located 140 km from Regina, Saskatchewan (Figure 1) and lies within the mixed grass ecozone. The lake is divided into 12 interconnected basins to manage water levels and facilitate extraction of sodium sulfate (Figure 2). Shoreline beach width varies and averages about 100 m wide (MacDonald et al. 2003). Beaches consist of mud, gravel and cobble and are sparsely vegetated with alkali cord grass (*Spartina gracilis*), baltic rush (*Juncus balticus*), Nuttall's salt-meadow grass (*Puccinellia nuttallinana*), salt grass (*Distichlis stricta*), and seaside arrow-grass (*Triglochin maritime*) (MacDonald et al. 2003). The lake is predominantly surrounded by native pasture and wetlands (MacDonald et al. 2003). Chaplin Lake is an important breeding site for Piping Plovers, supporting up to 6% of the Northern Great Plains

Figure 1. Location of Chaplin Lake in southern Saskatchewan.

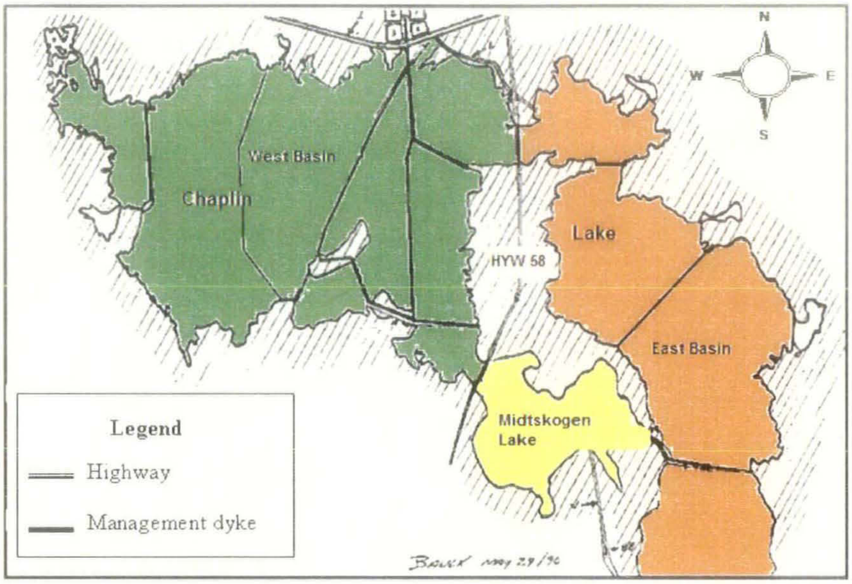

Figure 2. Adapted schematic drawing of Chaplin Lake, Saskatchewan showing management dikes and interconnected basins.

population and 15% of the Saskatchewan population (Dunlop 2001, Ferland and Haig 2002). Chaplin Lake is recognized as both a Western Hemisphere Shorebird Reserve Network and an Important Bird Area (Schmutz 2000) due to its use by high numbers of breeding and migrant shorebirds. This study was carried out primarily on two basins within Chaplin Lake, hereafter called East Basin and West Basin (see Figure 2). The South Basin was not included in the project's study area. Midtskogen Lake (50° 24' N, 106° 39' W) was surveyed during the pair survey but not for productivity purposes.

3.0 Methods

A pair survey was conducted on 30 and 31 May 2005. The entire shoreline of the East and West basins of Chaplin Lake and Midtskogen Lake was searched. Beaches on the East and West basins were walked by pairs of observers walking parallel transects staying close to the vegetation line stopping periodically to scan for plovers with binoculars and scopes. Midtskogen Lake was searched with an All Terrain Vehicle. Searchers examined plovers for colour leg bands. All sightings were recorded as either singles or pairs; territorial, non-territorial, or unknown; and the total number of adults seen. Pairs were recorded as birds seen together and adults with associated nests and/or young were tallied separately. At each sighting, Global Positioning System (GPS) coordinates were recorded as well as colour band combinations and any nest information.

Piping Plovers were monitored at Chaplin Lake, Saskatchewan from 9 May to 5 August 2005. Methodology generally followed Murphy et al. (1999). Nest searches were conducted on beaches of the East and West basins and all shorelines on these basins were covered a minimum of once per week during egg laying. All nest searches were conducted on foot. All nests found were marked with a shim labeled with a six alpha-numeric value (lake-year-nest no.) and a small rock cairn. GPS coordinates were also recorded so that nests could be easily relocated. Nest initiation was determined preferentially by (1) egg laying sequence when discovered prior to clutch completion, (2) floating eggs of nests with full clutches (Schwalbach 1988), or (3) backdating from hatch dates when the previous methods were not possible or accurate. Estimated hatch dates were calculated by adding an estimated 34 days (seven days egg laying and 28 days incubation, Murphy et al. 1999) to the nest initiation date. Nests were monitored one or two times a week and more frequently near the expected hatch day to assess nest success/failure and to determine hatch/termination dates.

Hatch dates were determined preferentially by (1) observing young in the nest bowl (using the hatch date of the first chick if hatching was not synchronous), (2) using the hatch date estimate derived from the egg laying sequence or egg flotation (if these estimates were reasonable, i.e., fell within the dates the nest was visited), (3) using the day before chicks were first discovered when visits were less than five days apart (if hatch date estimates were not reasonable, i.e., fell beyond the dates the nest was visited), or (4) using the midpoint date when visits were greater than five days apart. Ages of young found without an associated nest were estimated from body mass and this age was then backdated to determine the hatch date. As not all adults were marked, we could not be certain which nests were first nests or re-nests so we defined early nests as those initiated on or before 8 June and late nests as those initiated after 8 June.

We defined clutch size as the maximum number of eggs observed in a nest and the incubation period as the time from the laying of the last egg to the hatching of the first chick. Both apparent (number of successful nests/total number of nests) and Mayfield (Mayfield 1961, 1975) nest success were calculated. Using these two methods allowed us to compare nest success with other studies that used only one of these measures. Incubation periods were calculated for all nests with estimated initiation and hatch dates and excluded nests which were destroyed. Inaccuracies in age determination by floating eggs may bias measures of the incubation period.

All nests incubated less than 23 days were considered to have failed and were attributed to predation unless evidence of flooding or other cause of failure existed. Nest fate was recorded as unknown if eggs went missing within five days of the estimated hatch and no chicks could be clearly ascribed to the nest (territory ambiguous) or there was an absence of persistent, intensive displays by the parents. Nests were considered abandoned after a minimum of three nest visits with no attending adult and no obvious nest tending. A single egg was turned so that the large end pointed inward rather than outward in nests suspected to have been abandoned. The egg was turned after two or more visits with no attending parent or evidence of nest neglect (e.g., partially filled scrapes with blown sand). The nest was subsequently checked before egg collection. Abandoned eggs were collected, wrapped in tin foil, and frozen until transport at the end of the season. Collected eggs were measured, viability determined and embryos aged by the Canadian Cooperative Wildlife Health Centre in Saskatoon, Saskatchewan. Nests were considered successful if one or more eggs hatched.

Chicks were banded with a United States Fish and Wildlife Service metal band and a bicolour dark green-light green celluloid band as well as an additional two to three Darvic colour bands in combinations unique to the brood. In total, 141 Piping Plover young from 59 different broods were banded. Two brood monitoring methods were employed: traditional observation and radio telemetry.

Two observers monitored broods using traditional methods. Broods were followed every two to four days until they could fly, were 25 days of age or could not be relocated. Observers recorded the number of chicks present, bands (if used to identify the brood), location (Universal Transverse Mercator (UTM) grid system), time spent searching, general habitat, and weather at each observation. These brood observations over time were used to estimate fledging success and create a brood encounter history. These observers were naïve to brood successes, failures and movements as determined through radio telemetry. Each brood suspected to have failed was checked a minimum of two additional times before being considered as failed. Chicks were considered fledged when they had reached 18 days of age. The Canadian Wildlife Service (CWS) monitored broods on the lake until 5 August 2005. Thereafter, opportunistic band reading was done by SWA for the following two weeks while monitoring the release of captive-reared young (White and McMaster 2006).

Estimated hatch dates were carefully monitored to band and radio-mark young at approximately five days of age. After an effort to ensure a complete brood count, chicks were captured with butterfly nets and held in a well-ventilated container for processing. Each captured chick in the brood was weighed at banding to the nearest 0.1 g. If the chicks were less than 10 g at banding, attempts were made to return in approximately two days to re-weigh and attach the transmitter in an effort to keep the mass of the radio-transmitter and glue below five percent of the chicks' body mass. Chicks were uniquely banded as broods. Every other brood was selected in sequence of discovery regardless of age for radio-telemetry until radios had been used up. One or two young were randomly chosen from captured broods and fitted with a radio transmitter. These radio-marked young had a red band added to their band combination at the time of transmitter attachment to help in their identification following transmitter loss or failure.

BD-2N, 0.51g transmitters from Holohil Systems Ltd. were used to track chicks. The top and sides of each radio were lightly painted with flat grayish-brown model paint to eliminate shine and provide some camouflage. Chicks were held in the left hand with their heads between the second and third fingers, and their wings between the first and second fingers and the third and fourth fingers (Warnock and Warnock 1993). A second researcher assisted in gluing the transmitter to the intrascapular region using Instant Krazy Glue®. We attempted to separate the down to attach the transmitter as close to the skin as possible. We then lightly glued the surrounding down and/or feathers to the sides of the radio as the glue held better to down and feathers rather than skin. Chicks were held until the glue had completely set and were then re-weighed. On the younger smaller chicks, antennas were trimmed slightly to prevent dragging. The effect of antenna trimming on signal wandering and strength was tested prior to the study and no noticeable differences between trimmed and untrimmed antennas were found. The mean brood handling time for banding and transmitter attachment was 18 min with a maximum of 33 min (n = 59).

All captured siblings were released at the same time and in the vicinity of a calling parent. Attempts were made to observe all released chicks recently radio-marked to record the time required to return to the activity they were engaged in prior to capture.
Attempts were made to re-capture radio-marked young weekly to re-glue transmitters if needed and to re-weigh the chicks. This was especially important as young began to replace down with feathers making transmitter attachment less secure.

Radio-marked young were re-located with R-1000 telemetry receivers (Communications Specialists Inc.) and folding 3-element Yagi antennas. Shoreline searches extended a minimum of 2 km on either side of the nest and the entire shoreline was searched numerous times throughout the summer for missing signals. Time constraints did not permit searching upland areas for radioed chicks. The status of radio-marked young and any other observed brood-mates, their locations (UTM) and any changes in radio frequency was recorded. Remains accompanying relocated transmitters confirmed chick mortality and helped in determining the source of mortality.

Brood movement was calculated separately for traditional and telemetry observations. Initial capture, banding and radio-tagging locations were included for both traditional and telemetry observations. Broods and/or individuals identified by band combinations were included in both sets of observations. The median, mean, standard deviation (SD) and maximum values given were derived from broods known to survive to the end point of each age category. By combining traditional and telemetry observations, over 1100 brood locations were collected from hatching to fledging.

One hundred and eighty-four body mass measurements were taken from chicks of known age throughout the 2005 breeding season (Appendix 1). Each chick was weighed at banding and radio-tracked chicks were weighed opportunistically when they were re-captured to check the radio-attachment. Siblings of radio-marked chicks were also captured for re-weighing when possible. Body mass was measured to the nearest 0.1 g using a Pesola spring balance and were corrected for the mass of the weighing bag and radio-transmitter (if applicable) but not the bands. The average mass for the radio-transmitter and glue was 0.6 g (n = 62). Nearly all measurements were taken at 20 days and younger (Figure 3) with the majority of measurements from nonradioed young being

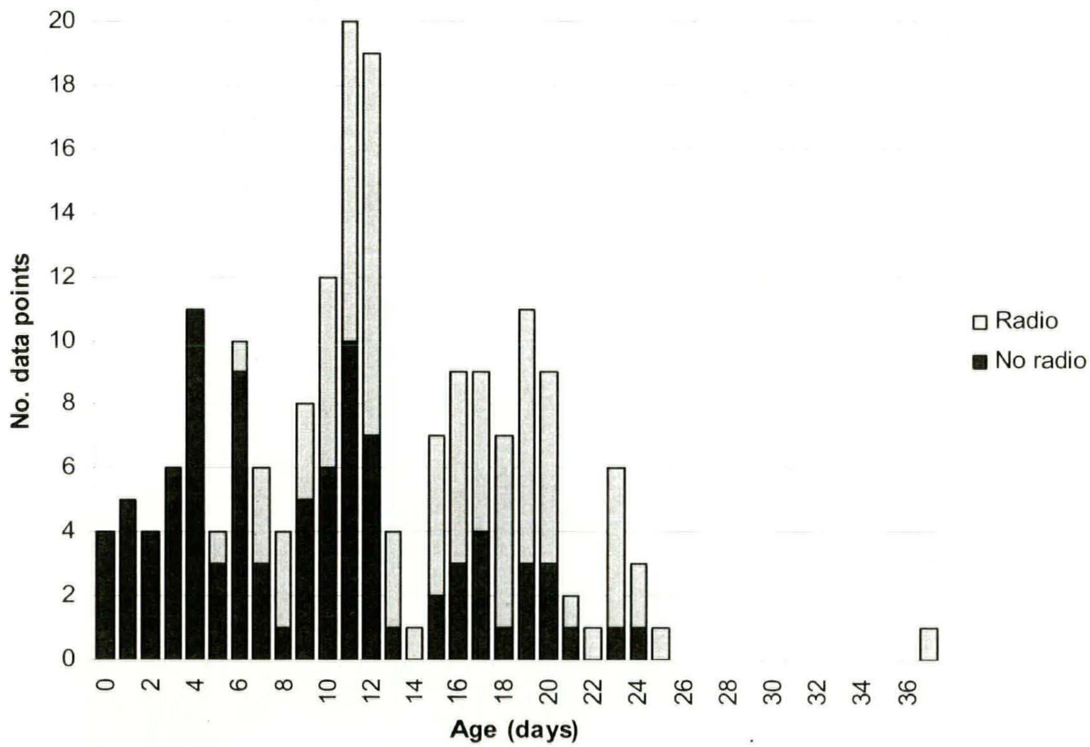

Figure 3. Number of mass samples taken of known aged radioed and nonradioed Piping Plover chicks at Chaplin Lake, Saskatchewan, 2005.

12 days and younger.

Body mass was fitted to the Gompertz equation which is most commonly used to estimate shorebird growth (e.g. Beimtema and Visser 1989, Reed et al. 1999, Ruthrauff and McCaffery 2005). Mass was also fitted to the logistic curve for comparison as these are the two most common growth equations (Ricklefs 1973). Graphs produced using the Gompertz equation show a more prolonged, slower growth rate at the later stages of growth compared to the logistic equation (Ricklefs 1967).

Gompertz: W= Ae^(-e^(-K(t-I)))
Logistic: W= A/(1+e^(-K(t-1)))
Where W= mass at time t (days), A= final mass or asymptote, I= inflection point, and K= constant proportional to the overall growth.

The curves were fitted using non-linear regression in Systat (r^2 = 0.97). The data were weighted against accuracy of determining hatch. Observed hatch was given the highest weighting, followed by estimates obtained from observing the egg laying sequence or floating eggs at full clutch. The asymptotic mass (A) was fixed as the mean adult mass of 53.4 g and the growth rate constant, K, and the inflection point, I, were estimated. The asymptotic mass was calculated using the average adult mass of individuals measured in Manitoba, Minnesota, New York, Nova Scotia, and Saskatchewan (n = 473) (Haig and Elliott-Smith 2004; C. Gratto-Trevor unpubl. data; U. Banasch unpubl. data). Both male and female masses from a variety of sites were used as adult mass does not differ by site and male and female mass overlaps in each population (Haig and Elliott-Smith 2004).

4.0 Results

4.1 Population status

Fifty-nine pairs and 82 singles were counted for a total of 200 adults (Table 1) during the pair count. Plovers occurred throughout most of the East and West basins but were concentrated on the southeast shore of the East Basin and the south shore on the West Basin (Figure 4). Given the number of pairs (59) and the number of territorial singles (37) counted during the survey, the number of pairs present on the lake is estimated at 96 pairs. A minimum of 88 nests were known to be active at one time (11 June 2005), not including

Table 1. Chaplin Lake Piping Plover pair count results, 2000 to 2005 (White 2004, this study).

Year	East Basin		West Basin		Midtskogen Lake		Total birds
	Pairs	Singles	Pairs	Singles	Pairs	Singles	
2000							166
2001	2	10	20	34			88
2002	1	10	8	31	1	10	71
2003	9	19	26	56	1	1	148
2004	13	24	26	25	5	7	144
2005	37	47	21	34	1	1	200

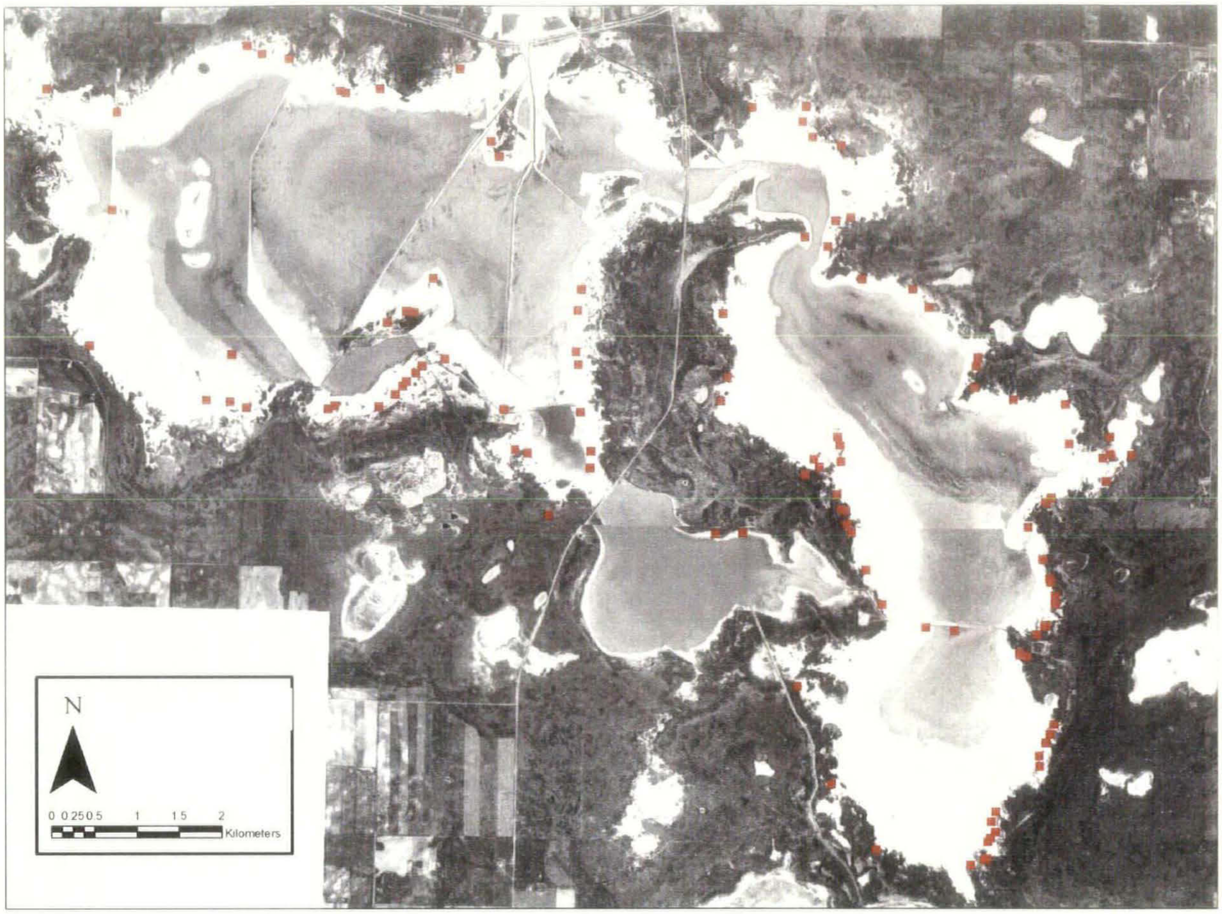

Figure 4. Locations of Piping Plovers recorded during the pair count, 30 and 31 May 2005 at Chaplin Lake, Saskatchewan.

nine nests with unknown initiation dates. One hundred and five nests were initiated on or before 8 June 2005, which is the date used to determine late nests.

4.2 Nesting Chronology

4.2.1 Weather and clutch initiation

In 2005, Chaplin Lake and the surrounding area received slightly below average precipitation throughout the winter. By the end of May, precipitation had risen to average levels and remained at average to above average throughout the remainder of the breeding season (Figure 5). High water levels in Midtskogen Lake resulted in little available habitat; however, there was an abundance of habitat available on both the East and West

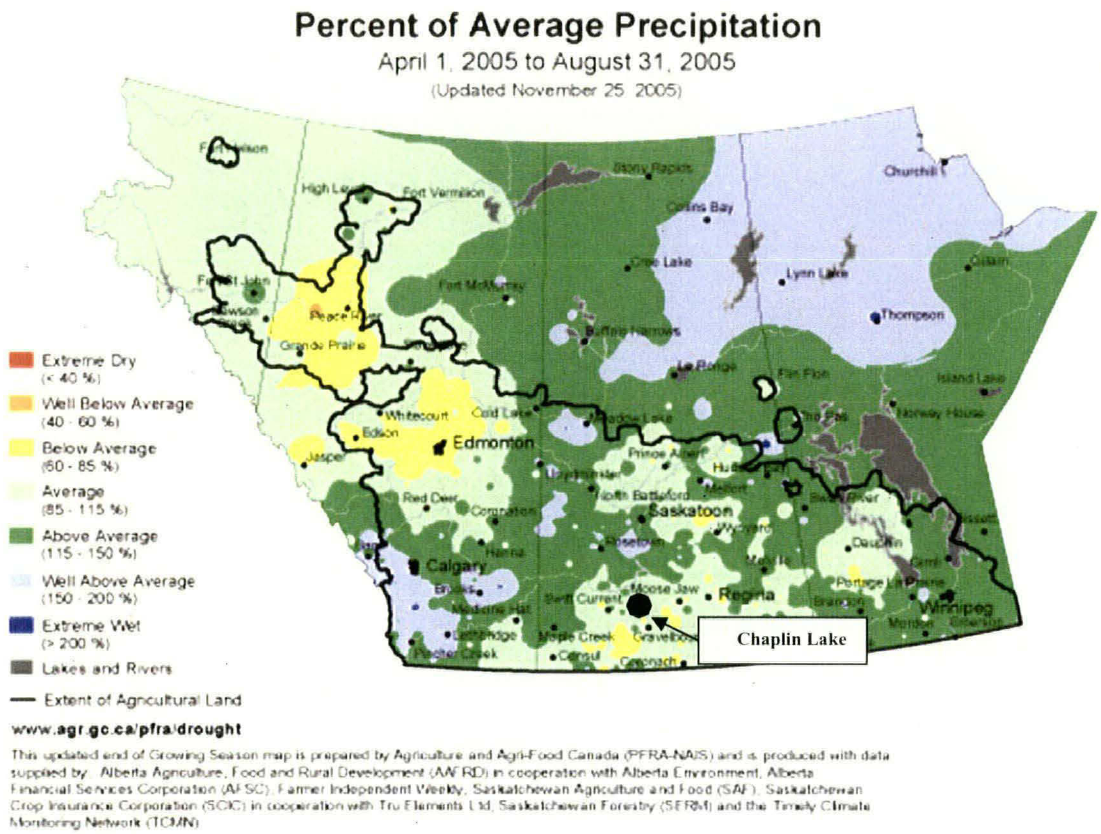

Figure 5. Percent of average precipitation over the Canadian Prairies during the 2005 growing season (www.agr.gc.ca/pfra/drought/drmaps).

basins. Egg laying occurred from 8 May to 7 July 2005 with a mean nest initiation date of 27 May ± 13 days (n = 115, Figure 6) and a median of 21 May.

4.3 Productivity

4.3.1 Nesting effort and clutch size

Throughout the summer 123 nests and 11 broods without an associated nest were located and observed on the East and West basins (Figure 7). Four hundred and sixty-six eggs were laid in 123 nests. The average clutch size was 3.87 ± 0.04 (SE) (Table 2), excluding

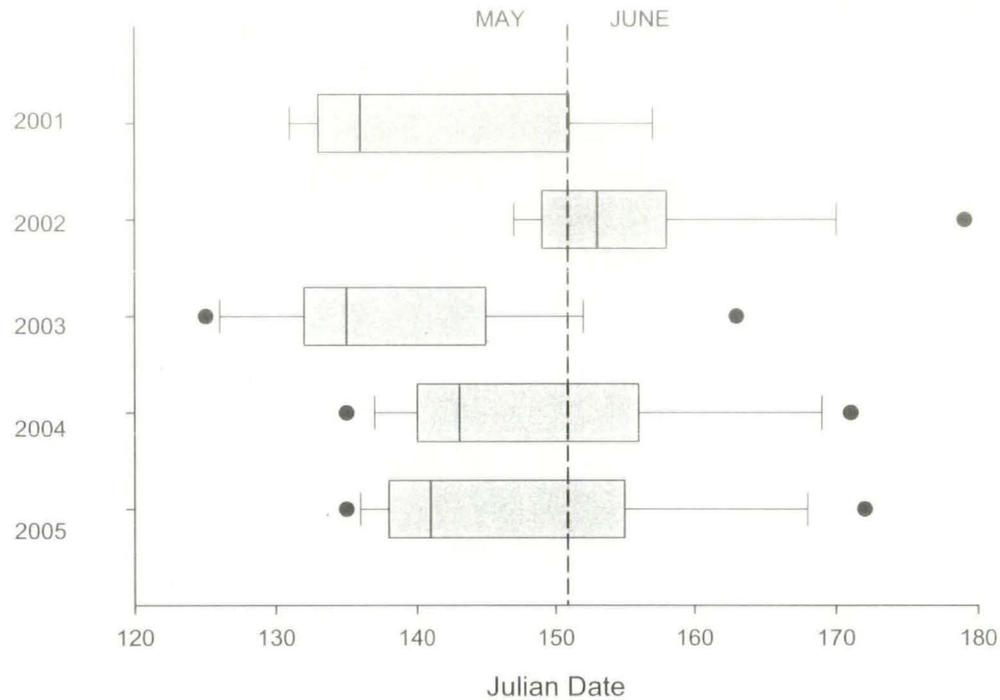

Figure 6. Temporal patterns of Piping Plover clutch initiation at Chaplin Lake, Saskatchewan, 2001 to 2005 (White 2004, this study). The box represents the 25th, 50th and 75th percentile; the whiskers represent the 10th and 90th percentile and the dots represent the 5th and 95th percentile. The median is shown by the vertical line in each box.

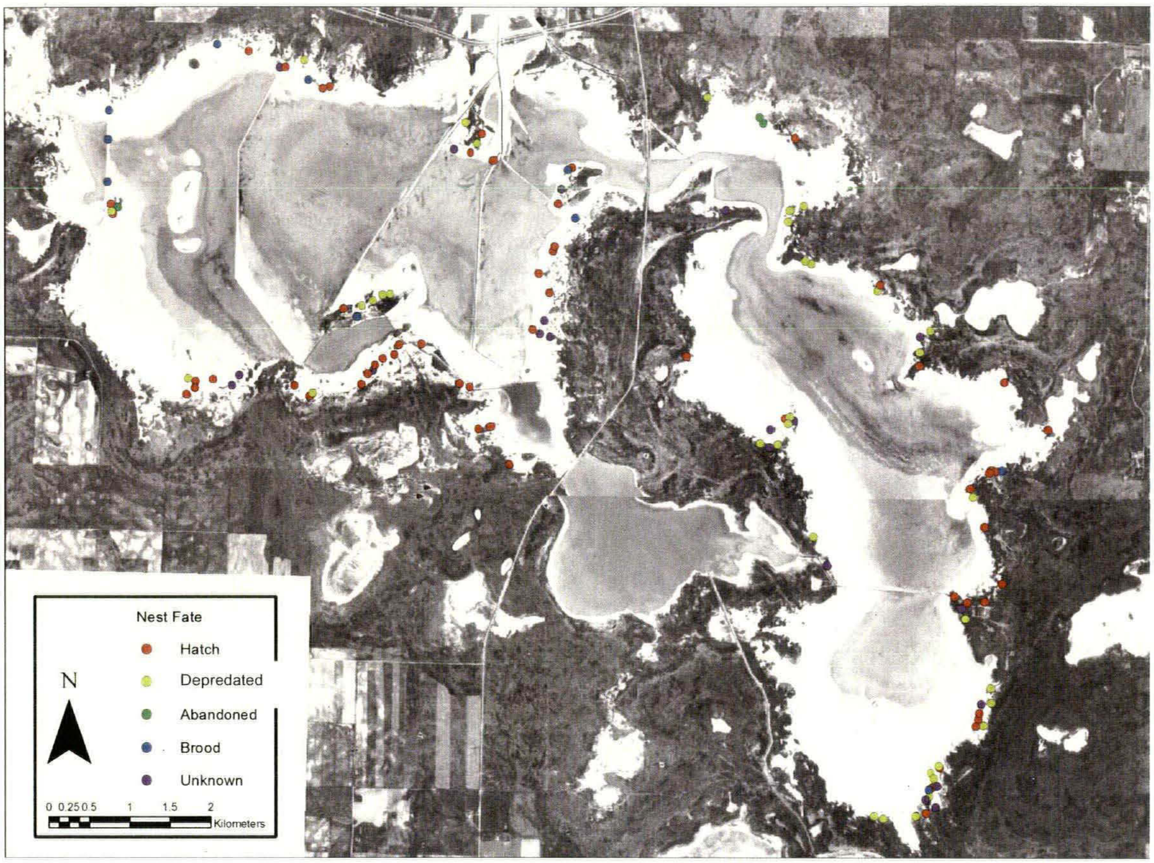

Figure 7. Piping Plover nest locations and fate at Chaplin Lake, Saskatchewan 2005.

Table 2. Number of Piping Plover nests found, clutch size, clutch fate and apparent nest success at Chaplin Lake, Saskatchewan, 2001-2005 (White 2004, this study).

Year	No. Nests	Mean Clutch Size	Depredated	Abandoned	Flooded	Trampled	Unknown	Hatch	Apparent Nest Success
2001	67	3.8	17 (25.4%)	0	0	0	14	36	67%
2002	36	3.6	7 (19.4%)	2	0	0	2	25	68%
2003	41	3.5	4 (9.8%)	0	0	1	0	36	87%
2004	75	3.7	28 (37.3%)	1	5	1	0	40	54%
2005	123	3.8	43 (35.0%)	3	2	0	14	61	56%

seven nests (including 17 eggs) that were known or possibly destroyed during egg-laying. The majority of all nests (82%) consisted of four eggs with a higher percentage of nests initiated after 8 June having smaller clutch sizes (Table 3).

Table 3. Piping Plover clutch sizes of nests initiated before and after 8 June 2005 at Chaplin Lake, Saskatchewan.

Nest period	Clutch size					
	1 egg	2 egg	3 egg	4 egg	5 egg	Total
Early nest[1]	1 (1%)	2 (2%)	7 (7%)	84 (88%)	1 (1%)	95
Late nest[2]	0 (0%)	2 (8%)	7 (29%)	15 (63%)	0 (0%)	24
Unknown initiation date	0 (0%)	1 (25%)	1 (25%)	2 (50%)	0 (0%)	4
All nests	2 (2%)	5 (4%)	15 (12%)	101 (82%)	1 (1%)	123

[1] On or before 8 June.

[2] After 8 June.

4.3.2 Nest success

Sixty-one (49.6%) of 123 nests found were known to be successful (Table 4). Apparent nest success was 56.0% and Mayfield nest success was 38.4% ± 0.02 SE. Daily nest survival rate was 0.9731. The West Basin had higher nest success than the East Basin throughout the nesting period (Figure 7) and higher nest success for nests initiated after 8 June 2005 (Table 5). Due to the large number of nests classified as "unknown" (n = 14) a bias likely exists, as both successful and unsuccessful nests are not likely to have the same probability of being categorized as unknown. Of the 14 nests classified as unknown, five were suspected depredated; however, it is impossible to tell whether the predation event occurred at the egg or chick phase as all eggs went missing within five days of the estimated hatch. These nests had coyote (*Canis latrans*) tracks in the vicinity or minor levels of disturbance to the nest bowl. Two nests did not have eggs floated before they were destroyed so their incubation stage and estimated hatch date were unknown. If the five suspected depredated nests are assumed to have occurred before hatch, the Mayfield estimate is 34.8%.

Table 4. Piping Plover clutch fate in relation to clutch initiation at Chaplin Lake, Saskatchewan, 2005.

Nesting period	Initiated	Hatched	Depredated	Abandoned	Flooded	Unknown Fate
Early[1]	95	50 (53%)	30 (32%)	1 (1%)	2 (2%)	12 (13%)
Late[2]	24	11 (46%)	11 (46%)	2 (8%)	0 (0%)	0 (0%)
Unknown [3]	4	0 (0%)	2 (50%)	0 (0%)	0 (0%)	2 (50%)
All nests	123	61 (50%)	43 (35%)	3 (2%)	2(2%)	14 (11%)

[1] On or before 8 June.

[2] After 8 June.

[3] Clutch initiation date unknown.

Table 5. Mayfield Piping Plover nest success by location and nesting period at Chaplin Lake, Saskatchewan, 2005.

Basin	Nest period	No. failed clutches	Total exposure days	Mayfield nest success	Standard error	Confidence Interval (98%)
East	Early[1]	21	738	0.3641	0.0363	0.2915-0.4366
East	Late[1]	12	162.5	0.0682	0.0755	-0.0828-0.2192
West	Early	12	687	0.5397	0.0378	0.4641-0.6153
West	Late	1	182	0.8246	0.0739	0.6768-0.9725

[1] Early nests initiated on or before 8 June; late nests initiated after 8 June.

4.3.3 Egg mortality

Predation accounted for the majority (69%) of known nest losses. No nests were reportedly lost to livestock trampling, two were suspected to have flooded (standing water was observed in the nest area on the visit following heavy rain) and none were known to have flooded as the result of water management activities. Three nests were abandoned. Nest CH-05-14 had a full clutch of four eggs and was estimated to be five to 10 days into incubation when it was abandoned. All four eggs were determined to be infertile (Canadian Cooperative Wildlife Health Centre, pers. comm.). Nest CH-05-105 had two eggs that were incubated a minimum of 16 days (from discovery to abandonment) but is estimated to have been incubated for at least 25 days. Both eggs were collected at an estimated 31 days past initiation of incubation; both were fertile and had embryos that weighed 4.7 and 5.2 g. CH-05-123 had a clutch of three eggs which was estimated to be at seven days incubation when the eggs were abandoned. All three eggs were fertile and had embryos weighing from 0.2 to 0.6 g. An attending adult was present for a minimum of two visits following nest discovery for each abandoned nest suggesting that abandonment was not the result of investigator disturbance.

Of the 123 nests and 466 eggs monitored, 39% of complete clutches and 64% of individual eggs (Figure 8) were lost in the egg phase. The majority of complete clutch losses (> 20%) occurred 10 to 20 days before hatch (Figure 9). Eleven nests experienced partial egg predation or accidental removal by the incubating parent. Accidental parental egg removal was evidenced by video monitoring at Chaplin Lake and was recorded for three nests during 2002 and 2004 (White 2004). At these nests, six nests lost a single egg and the remaining five nests lost two eggs for a total of 16 eggs.

Seven nests experienced partial abandonment after one or more siblings hatched. One pair abandoned three eggs after a single egg hatched, two pairs abandoned two eggs after siblings hatched, and four pairs abandoned a single egg after at least one chick hatched. More pairs may have abandoned infertile or delayed eggs as eight more nests had asynchronous hatching where the fate of the remaining eggs could not be determined.

Three eggs were collected from nest CH-05-119 after a single egg hatched 14 days earlier. The eggs were damaged when collected. One egg was determined to be infertile and the other two could not be determined. A single egg was collected from nest CH-05-89, 15 days after the other three eggs hatched. The egg was damaged and it could not be determined if it had been fertile or not. The remaining egg from nest CH-05-121 was collected. That egg was fertile with an embryo weighing 7.7 g.

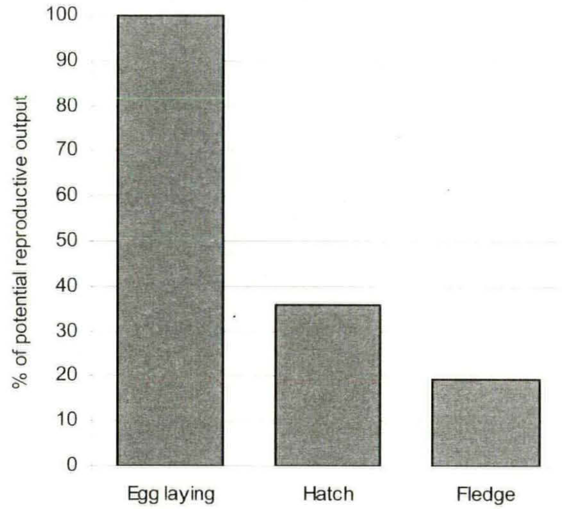

Figure 8. Piping Plover reproductive potential at egg laying, hatching and fledging (18 days) at Chaplin Lake, Saskatchewan, 2005. Potential begins at 100% of 466 eggs known to be laid in 123 nests. Numbers do not include 11 broods found without an associated nest.

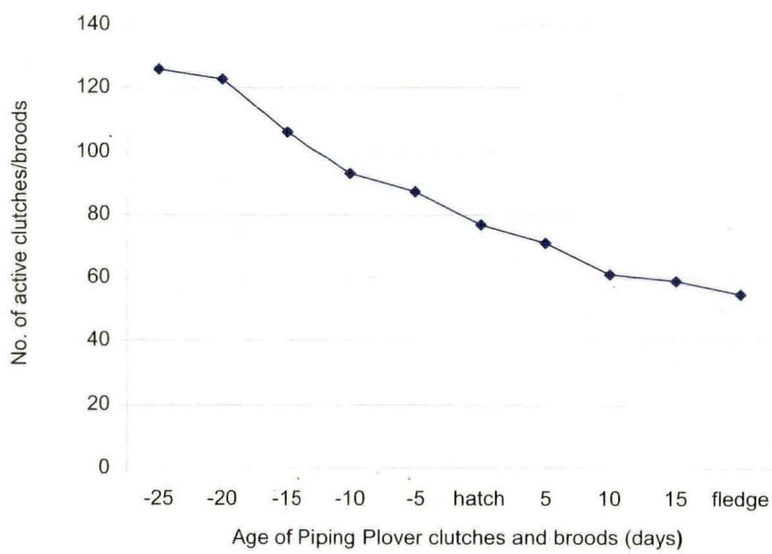

Figure 9. Age of Piping Plover clutch and brood loss from egg laying to fledging (n = 126) at Chaplin, Lake, Saskatchewan, 2005.

It was difficult to determine if eggs within each nest tended to hatch synchronously as each nest was visited only every few days. However, one nest (CH-05-30) was known to hatch over a period of at least three days.

4.3.4 Fledging success

Of 196 chicks known to have hatched, 111 (57%) Piping Plover young were known to survive to 18 days of age, 99 (51%) young survived to 20 days, and 78 (40%) young survived to 25 days. The number of chicks known to hatch is a minimum estimate as both eggs and full clutches with unknown fate were not included. Using the estimate of 96 pairs (range estimate 88-105), the fledging rates were 1.16 (range = 1.06-1.26), 1.03 (range = 0.94-1.13), and 0.81 (range = 0.74-0.89) Piping Plover young fledged per pair at 18, 20, and 25 days, respectively. Mayfield chick success was 25.9% (SE = 0.03)

4.3.5 Survival

Forty-five (74%) of the 61 radio-marked young were known to survive to 25 days of age. One chick could not be followed beyond the age of 20 days but it is assumed to have fledged as it moved to an island that was inaccessible to observers bringing the total to 46 (75%) young. Seven (11%) chicks went missing from the ages of 13 to18 days. One of seven radios was located. The radio was found the day following attachment and there were no obvious signs of predation but the chick was not re-sighted during the summer and is assumed to have died. Missing chicks were assumed lost to decimating factors as all radios were functioning on the previous visit. Seven (11%) of the remaining eight chicks aged 15 to 24 days were assumed dead from evidence accompanying the located radio-transmitter. The remaining chick (2%) was accidentally killed as a result of handling at 15 days of age. Of 15 chicks not known to survive to 18 days, 10 were missing or found depredated within six days of radio attachment, the remaining five went missing or were found depredated from eight to 11 days post-attachment.

4.3.6 Chick depredation

There was evidence for both avian and mammalian predation. Avian predation was assumed responsible for three of the seven recorded mortalities. Recovered radios were found with numerous feathers characteristic of plucking of prey by raptors (Figure 10).

Figure 10. Photograph of recovered radio-transmitter with Piping Plover predation evidence.

One site also included a single banded leg, another a severely twisted antenna, and none of the sites had any obvious mammalian predator tracks. Avian predators may be responsible for an additional two mortalities as two of the kill sites had no obvious tracks and few feathers accompanying the radio-transmitter. The remaining two mortalities appear to be mammalian. Both kill sites had legs and body chunks present, one had scat nearby and the other had obvious mammalian tracks. All known mortalities occurred in mid July (~10-23 July).

Predation on radio-marked young appeared to be independent within their broods. Of the seven radioed chicks known to be depredated, three were from single chick broods, one had a sibling that went missing on a previous visit, and the remaining three had siblings that survived to fledging. Of the seven missing chicks, two were the only remaining chicks in their broods, one had its remaining sibling depredated on the following visit, and four had siblings that survived to fledging. Only 10 young had radio transmitters attached when they were younger than 10 days of age with the youngest chick being five days old. Chick survival may not be as independent at younger ages.

4.3.7 Post-radio attachment behaviour

The mean time to return to activity prior to capture was approximately three minutes (n = 42). Five chicks took longer than five minutes to return to their previous activity and only one chick took longer than 10 minutes. Two chicks appeared to be significantly disturbed by the attachment of the transmitter. The first preened excessively with interruptions of walking backwards with its head lowered. The transmitter may have been placed too high on the back causing this unusual behaviour. The chick went out of sight after 12 minutes of observation. It was known to survive to a minimum of 23 days of age (11 days post-attachment) after which the radio and the chick's remains were discovered. The second chick ran normally immediately post-release but then proceeded to roll head-over-heels numerous times. This chick was known to survive beyond 25 days.

4.3.8 Detection probability

Observers using traditional methods failed to locate and identify six additional broods on the lake that were identified as new broods by the telemetry crew. The absence of these broods in fledging estimates would negatively bias survival.

4.3.9 Brood movements

Of 50 broods observed between hatching and five days, 20 moved 100 m or more from their nests sites, nine moved over 200 m, and three moved over 300 m (Table 6). One brood (CH-05-86) is believed to have moved over 600 m at approximately two days of age. This brood was not banded when found two days previously. At the time the chicks were newly hatched and still in the nest bowl. Numerous nest searches were conducted in the area and all known nests within one km were either known to be depredated or hatched two weeks previously. It is difficult to determine movement at this age as chicks were too small for radio-attachment and many go missing before the age of five days.

Of 59 broods with observations (traditional and telemetry) under 10 days, 39 moved over 100 m from their nest site, 17 moved over 200 m, four moved over 300 m, and two moved over 500 m. The mean movement of chicks younger than 10 days of age and known to survive the 10 day interval was 144 ± 112 m (Table 6). The median value was 127 m. Although many broods remained within 100 m of their nest site there were a number of broods that more than doubled this distance before reaching 10 days.

Table 6. Summary of distances (m) moved by Piping Plover young at Chaplin Lake, Saskatchewan in 2005, determined by both traditional and telemetric observations.

	10 days		18 Days		All Observations[1]	
	Traditional	Telemetry	Traditional	Telemetry	Traditional	Telemetry
Median (m)	127	130	182	215	4440	3689
Mean (m)	144	137	200	270	4491	4401
Standard deviation (m)	112	89	127	243	3937	3573
Maximum (m)	618	299	647	1350	13124	13108
No. of broods/individuals[2]	55	14	47	35	47	38

[1] All observations of young until no longer seen again.

[2] Traditional observations were of broods while telemetric observations were of individual chicks.

Three radio-marked broods moved over 500 m from their nest site when younger than 16 days of age. Two of these three broods moved this distance under 12 days of age. Brood movement was quite varied among broods and ranged from over 100 m to a few km. The maximum recorded distance of a brood not yet fledged was 1.35 km. The mean distance (270 m) moved by radio-marked broods younger than 18 days is higher than the mean distance (200 m) moved as recorded by observers not using telemetry (Table 6). The difference, however, was not statistically significant (Mann-Whitney *U*-Test, $P > 0.05$).

4.3.10 Growth and fledging

Mass measurements from radioed and nonradioed chicks of known age were used to determine growth parameters. Growth parameters for the Gompertz equation yielded a growth coefficient (K) of 0.084 and an inflection point (I) of 11 days (Table 7). This equation describes the complete range of growth from hatch to asymptote, which was given as the mean adult mass. Mass gain followed a sigmoid pattern (Figure 11). The fitted Gompertz growth curve was used to estimate age of chicks found without associated nests (Table 8).

Table 7. Estimated growth constant (K) and inflection point (I) for Piping Plover chick growth at Chaplin Lake, Saskatchewan for Gompertz and logistic growth equations.

Equation	K	I
Gompertz	0.084	11.271
Logistic	0.129	15.890

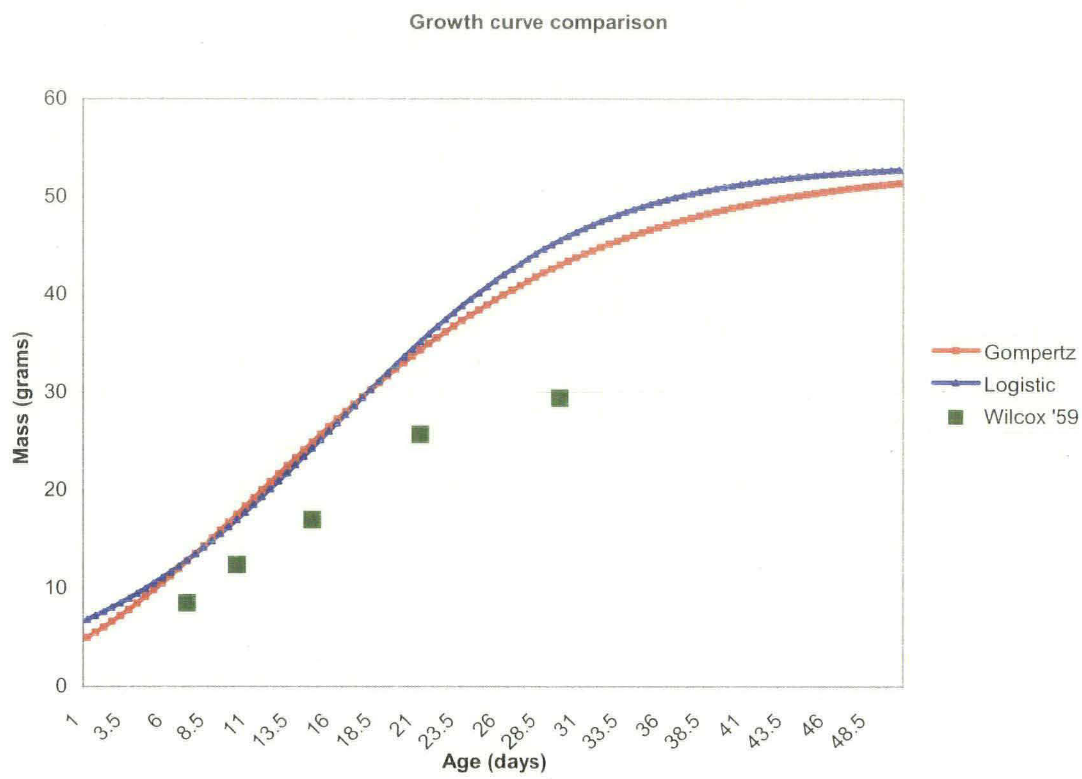

Figure 11. Logistic and Gompertz growth curves fitted to chick masses at Chaplin Lake, Saskatchewan, 2005.

Table 8. Age estimation chart based on fitted Gompertz growth curve derived from Piping Plover chick mass measurements at Chaplin Lake, Saskatchewan, 2005.

Age (days)	Mass (g)	Upper 95% C.I.[1]	Lower 95% C.I.
1	5.0	6.2	3.8
2	6.0	7.3	4.8
3	7.2	8.4	5.9
4	8.5	9.7	7.1
5	9.8	11.0	8.5
6	11.3	12.4	10.0
7	12.8	13.8	11.5
8	14.3	15.3	13.2
9	15.9	16.8	14.9
10	17.6	18.3	16.6
11	19.2	19.9	18.4
12	20.8	21.4	20.2
13	22.5	22.9	22.0
14	24.1	24.4	23.7
15	25.7	25.9	25.5
16	27.3	27.4	27.2
17	28.8	28.8	28.8
18	30.3	30.1	30.4
19	31.7	31.5	31.9
20	33.0	32.7	33.4
21	34.3	33.9	34.8
22	35.6	35.1	36.1
23	36.8	36.2	37.4
24	37.9	37.3	38.5
25	38.9	38.3	39.6

[1] C.I. = Confidence Interval

Observers noted age of first flight for 21 different broods of known age (not including young found without an associated nest). Age at first flight varied from 20 to 33 days with an average of 26 ± 3.45 days (SD). These numbers are likely biased high as broods were not monitored on a daily basis and observers did not chase all located broods to confirm ability to fly; however, nine broods were confirmed not capable of flight at 20 days of age and five were confirmed not capable of flight at 24 days. Young from 41 broods were sighted and known to remain on the lake over 30 days post-hatch, 28 remained 40 days post-hatch, and eight remained 50 or more days post-hatch.

5.0 DISCUSSION

5.1 Breeding biology

More (142%) plovers were counted on the East Basin than in the previous four years. The mean initiation date is within a day of the previous year and about nine to 11 days later than 2001 and 2003, respectively, and nine days earlier than 2002 (White 2004). Clutch initiation in 2005 was the least synchronous of all years from 2002 with a SD of 13.0 days (n = 115). Standard deviations of clutch initiation for 2002, 2003, and 2004 were 9.7, 10.2, and 11.3 days, respectively (White 2005). This is the highest number of nests recorded in the last five years (Table 2). Recent construction of two dykes in the East Basin resulting in more habitat created, may have contributed to the population increase in recent years (C. White, pers. comm.)

Estimated fledging rates at 18 days (1.16 chicks/pair) were slightly below the Piping Plover recovery strategy goal for *C. m. circumcinctus* of 1.25 chicks per pair Environment Canada 2006). Fledging success during 2005 is the highest reported for Chaplin Lake in the previous three years. White (2004) reported fledging success at 18 days as 0.69, 0.75, and 0.86 in 2002, 2003, and 2004, respectively. Fledging ages at Chaplin Lake in 2005 are comparable to other study areas and years. In Nova Scotia, Cairns (1982) also noted chicks 25 days old that were fledged (capable of flying over 15 m) and others of the same age that were not cable of flight over 2 m and reported that chicks at 28 and 32 days of age were flying well. Prindiville Gaines and Ryan (1988) reported fledging times of 21 to 28 days in North Dakota. Wilcox (1959) reported the oldest ages with young fledging at 30 to 35 days in New York.

5.2 Survival

Piping Plover brood survival has been reported in only a few other published studies (Prindiville Gaines and Ryan 1988; Loegering and Fraser 1995; Patterson et al. 1991; White 2005). Brood survival in past studies was reportedly most influenced by chick age

(Prindiville Gaines and Ryan 1988; Jung et al. 1998; Murphy et al. 2000, White 2005), with survival rates leveling off at 12 to 15 days (White 2005).

The fate of over 50% of chicks at Chaplin Lake is typically unknown. There are cumulative and interactive effects between food and predators making it difficult to find the root cause of death. The reported decreased daily survival rates of young Piping Plovers may be the result of starvation (Loegering and Fraser 1995), disturbance (Patterson et al. 1991) and exposure (Murphy et al. 2000). A higher rate of complete brood loss may occur when chicks are required to remain close for brooding before achieving thermal independence. The ability to locate and collect dead young at Chaplin Lake through telemetry helped determine causes of brood and individual chick loss.

Survival rates of radio-marked Piping Plover young were higher at Chaplin Lake than those radio-marked the previous year at Lake Diefenbaker (Martens 2005). Compared to 75% of 61 radio-marked young surviving to 25 days at Chaplin Lake only 45% of 22 radio-marked young at Lake Diefenbaker survived to 18 days (Martens 2005). Rising water levels at Lake Diefenbaker in 2004 resulted in minor loss of chick habitat (Westworth and Goossen 2004) and we believe that the narrower habitat was not a significant direct or indirect factor in the mortality of radioed chicks at this reservoir.

Prindiville Gaines and Ryan (1988) reported no mortality in Piping Plovers over 16 days of age, with all young seen after 16 days of age surviving to fledging. However, higher survival rates at older ages are not consistently reported for other plovers. Miller and Knopf (1993) reported that Mountain Plover (*Charadrius montanus*) chick mortality was spread over the development period rather than concentrated in the first few days post-hatch. The Mountain Plover daily survival rates for fledged and flightless birds were nearly identical, showing they were equally vulnerable to predators.

5.3 Predation

Depredation of Piping Plover nests and chicks appears to be a main factor in limiting productivity on the Northern Great Plains (see Haig and Oring 1987, Haig and Oring 1988, Prindiville Gaines and Ryan 1988, Richardson 1999, and Whyte 1985). Depredation of Piping Plovers has likely intensified in recent years as the predator complex changed with European settlement (Sauer et al. 2003) and continues to change with land use patterns and human activities (Burger 1987, Licht and Johnson 1992, Sargent et al. 1993, Kruse et al. 2001). Increases in predators that thrive in human-altered landscapes (Haig 1985) and a desire to develop more sustainable landscape level approaches to predation management (Westworth et al. 2004) have demanded a better understanding of chick predation.

Murphy et al. (2000) reports that reproductive losses at alkali lakes are split nearly in half with approximately half of the losses occurring during the egg stage and half during the chick phase. Egg predators are more easily identified than predators of chicks as evidence can be located at known nest locations or documented using cameras. Chick remains are rarely found and predation is rarely witnessed making it difficult to confirm plover chick predators. The only confirmed predator species of *circumcinctus* chicks are the Northern Harrier (*Circus cyaneus*) (Murphy et al. 2003; Ivan and Murphy 2005), American Kestrel (*Falco sparverius*) (Kruse et al. 2001), Great Horned Owl (*Bubo virginianus*) (Kruse et al. 2001), gulls (*Larus sp.*) (Miller 2006), mink (*Mustela vison*) (Kruse et al. 2001) and coyote (White 2004, Martens 2005). Of six known mortality events at Lake Diefenbaker in 2004, three were believed to be avian, two mammalian and one unknown (Martens 2005). Ivan and Murphy (2005) report that nearly all chick predation is from avian predators. Kruse et al. (2001) found that chick loss tended to be site-specific and related to the presence of nesting predators along the proximal shoreline.

Predator management, in the form of wire nest exclosures and electric fencing, has been highly successful at increasing hatching (Canadian Wildlife Service, unpubl. data, Larson et al. 2003) and fledging (Richardson 1999, Larson et al. 2003) success. Successful predator management during the egg phase needs to be followed by successful management during the chick phase to be effective at increasing productivity. Greater understanding of the relative importance of predators during the egg and chick phases is necessary. Predator identification is difficult as shorebird young are highly mobile, and predation events are rarely viewed. It is important to assess baseline productivity and the make-up of the predator community to help determine the best management options for predator exclusion (Johnson and Oring 2002).

5.4 Detection probability

Whether reported fledging rates are a reflection of real fledging success or are biased by traditional methods of estimating fledging success is unknown. Observations of young reported as not fledging provide evidence of bias in traditional methods of estimating fledging success. It is hard to quantify how many young survive and remain undetected as only a small percentage of banded young are re-sighted and studies that do band young often give siblings identical band combinations which then requires complete brood loss or re-capture. Of 241 hatchlings at Chaplin Lake in 2003 to 2004, 58% (142) were reported as not fledged at 18 days because their fate could not be determined (White 2004, Saskatchewan Watershed Authority 2003). Estimates of fledging success are compromised when the fate of more than half the chicks cannot be reliably determined.

Confidence in detecting individuals is influenced by nest density, beach size, and hatch synchrony and is further complicated by brood movement. The ability to detect a chick is also influenced by researcher ability, weather and age of the chick. Westworth et al. (2004) suggested that the extensive beaches on large alkali lakes might result in a lower detection probability than other used plover habitat due to survey difficulty. Observers may fail to detect the entire brood or individuals within a brood. Chicks under approximately 10 days require frequent brooding and therefore remain close to the attending parent facilitating in counting chicks. Problems with detection of either the brood or individual will negatively bias estimates of productivity.

White (2004) found bands to significantly improve the accountability of young allowing for identification in high-density areas and locations far from their nest sites. Telemetry will provide further accountability for moved birds and birds within searched areas that may be undetected due to habitat or behaviour. There has been an increase in adult banding and it is likely that fledging rates used in future modeling will be obtained from study sites that are banding. It is therefore important to examine the level of accuracy beyond banding.

No chicks were reported to have fledged from "Essex's beach" on the east side of the West Basin in the three previous seasons (C. White, pers. comm.). It is interesting to note that this stretch of beach provided some of the most extreme movement. One unmarked brood (CH-05-86) is believed to have moved over 600 m at approximately two days of age. A marked brood (CH-05-16) is known to have moved over 1 km by 11 days of age. Both broods moved south along the shoreline to a basin that contained considerably fresher water than the basin adjacent to their nest site. A minimum of five young were known to survive to fledging on this beach in 2005 and an additional six were known to survive on a neighboring island that connects to the mainland beach at low water levels.

It is important to improve the reliability and confidence of fledging success estimates as it is commonly measured and is a common parameter in population models. Fledging success has the potential to be influenced by management and is used as a measure for recovery. This study serves to evaluate the accuracy of traditional brood counts by allowing for greater accountability of broods.

5.5 Brood movements

Little has been reported on plover chick movements under 10 days of age other than personal observations on generally limited movement from the nest. Murphy et al. (1999) reports that chicks younger than 10 days of age generally stay within 50 to 100 m of their nest sites. Plover chicks require frequent brooding under the age of 10 days and this may contribute to the lack of brood movement at this age. It was difficult to measure brood movement under 10 days in this study due to limited observations which may result in underestimated movement. Chicks near or at the flight stage (21 to 28 days) are reported to wander up to 500 m from their nest sites and there are reports of 14-day old chicks observed over 600 m from their natal sites (Murphy et al. 1999). The movement of an unfledged brood of over 1 km and greater recorded median, mean and maximum distances at 18 days of age despite a smaller sample size suggests that a greater search area may be required on large alkali lakes to locate undetected broods thereby reducing the error of counting these broods as failed in productivity analyses when in fact they were still alive.

5.6 Chick growth

Growth data are relatively scarce for Charadriidae. This may be due in part to the difficulty in locating and re-locating young that are precocial and very cryptic (Miller and Knopf 1993). Telemetry allows for the re-location and capture of known individuals and mass is easily and reliably measured in the field by observers. We wanted to (1) describe the pattern of growth of Piping Plover chicks and compare them to other shorebirds and (2) provide a method to predict age at certain masses as well as estimate hatch dates. Chicks that were then previously of an unknown age can be included in estimations of productivity. Wild chicks may not experience mass gain immediately post-hatch and may even experience a mass loss over the first 24 to 48 h (Reed et al. 1999). This period of suspended mass gain or possible mass loss is not captured well by the model and may be responsible for the low estimated hatch masses. The mean hatching mass of captive-reared chicks at Lake Diefenbaker in 2005 was 7.40 ± 0.79 (n = 213) (White and McMaster 2006). Mass increases are slowed by the growth of primary and secondary growth feathers (Haig and Elliott-Smith 2004).

Cairns (1982) believed chicks that failed to achieve 60% of normal mass by day 12 in Atlantic Canada were unlikely to survive. The Gompertz model estimates that most chicks at Chaplin Lake in 2005 reached 60% of adult mass at approximately 19 days. The six masses from New York reported by Wilcox (1959) are considerably lighter than expected by both growth curves for Chaplin Lake chicks (see Figure 11). Haig and Elliott-Smith (2004) report chick masses from 6.3 to 7.2 g at one day, 8.8 to 16.9 g at 10 days and 35.6 to 37.2 g at 21 days. The wide range of masses at 10 days and subsequent narrow range at 21 days may be due to the death of lighter chicks. Variability in mass among individuals is likely greater around 10 days of age (Haig 1992). Masses of chicks known or suspected to have died before fledging were not consistently below the fitted Gompertz growth curve (Figure 12). This suggests that radio-marked young at this age were not necessarily succumbing to predation or exposure due to a weakened state from starvation.

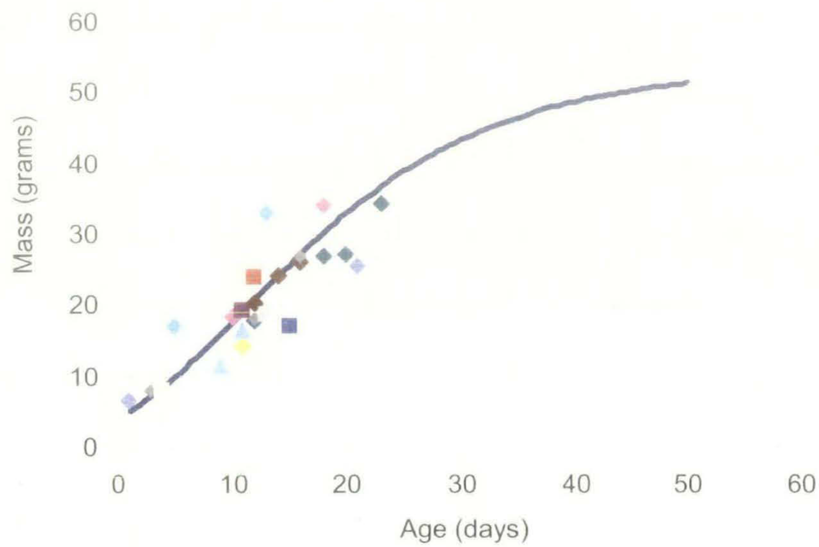

Figure 12. Masses of Piping Plover young known or suspected of dying before fledging plotted against a fitted Gompertz growth curve for Chaplin Lake, Saskatchewan (2005). Symbols with the same shape and colour represent the same bird.

Piping Plovers grow slightly faster than Hawaiian Stilt (*Himantopus mexicanus*) chicks and European Golden-Plover (*Pluvialis apricaria*) chicks with estimated K values of 0.065 (Reed et al. 1999) and 0.052 (Pearce-Higgins and Yalden 2002), respectively, and slower than Western Sandpipers (*Calidris mauri*) with a growth coefficient of 0.109 (Ruthrauff and McCaffery 2005). Weather conditions are known to have an effect on growth rate and fledging age of wader species (see Pearce-Higgins and Yalden 2002) and may have contributed to the spread in fledging ages reported in this study.

Piping Plovers appear capable of fledging at approximately 62% of the adult mass, although many fledged at higher mass percentages. The percentage of body mass at which shorebirds (Scolopacidae and Charadriidae) fledge varies from 53-91% (Beintema and Visser 1989). Mountain Plovers are capable of fledging at approximately 70% of the adult mass (Miller and Knopf 1993), and European Golden-Plover chicks at 71.7% of the adult mass (Pearce-Higgins and Yalden 2002). Hawaiian Stilt chicks fledge at about 28 days and they weigh only 60% of the adult body mass. This trend of continued growth to adult size after fledging is typical for most shorebirds. The presence of radio-transmitters appeared to have a minimal effect on time to fledging compared to siblings without radio-transmitters with most broods fledging synchronously (within approximately three days). Only one brood with radioed young fledged about four to five days later than their nonradioed siblings (CH-05-07). Pearce-Higgins and Yalden (2002) found no significant difference between the fledging times of radioed and nonradioed European Golden-Plover chicks. They also found that all chicks fledged within a three to six day window with a mean fledging age of 37 ± 1.1 days (SE) and 36.4 ± 0.95 days (SE) for radioed and nonradioed chicks, respectively.

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APPENDIX

Appendix 1. Masses of Piping Plovers of known age, including age accuracy and radio transmitter status at Chaplin Lake, Saskatchewan (2005).

Nest no.	Band no.	Mass (g)	Age (days)	Age accuracy[1]	Radioed[2]	Radio status[3]
CH-05-29	1951-49324	19.3	11	1	yes	attachment
CH-05-29	1951-49324	34.0	19	1	yes	yes
CH-05-29	1951-49324	38.6	23	1	yes	yes
CH-05-43	1951-49325	19.6	10	1	no	
CH-05-43	1951-49326	19.5	10	1	no	
CH-05-43	1951-49327	18.2	10	1	yes	attachment
CH-05-43	1951-49327	31.9	18	1	yes	yes
CH-05-06	1951-49328	33.3	17	1	no	
CH-05-94	1951-49329	18.5	10	1	yes	attachment
CH-05-94	1951-49329	34.1	18	1	yes	no
CH-05-94	1951-49330	19.2	10	1	no	
CH-05-41	1951-49331	19.2	10	1	yes	attachment
CH-05-41	1951-49331	34.5	18	1	yes	yes
CH-05-41	1951-49331	34.0	20	1	yes	yes
CH-05-40	1951-49340	13.0	11	3	no	
CH-05-40	1951-49341	14.2	11	3	yes	attachment
CH-05-40	1951-49342	13.8	11	3	yes	attachment
CH-05-40	1951-49342	31.9	19	3	yes	no
CH-05-40	1951-49343	12.8	11	3	no	
CH-05-40	1951-49343	29.0	19	3	no	
CH-05-38	1951-49344	15.3	5	3	no	
CH-05-38	1951-49345	17.1	5	3	yes	attachment
CH-05-38	1951-49345	33.1	13	3	yes	yes
CH-05-33	1951-49347	14.9	11	3	will	
CH-05-33	1951-49347	25.6	17	3	yes	attachment
CH-05-33	1951-49347	32.2	23	3	yes	yes
CH-05-17	1951-49348	25.1	16	4	yes	attachment
CH-05-17	1951-49349	24.7	16	4	no	
CH-05-37	1951-49350	17.6	12	1	yes	attachment
CH-05-37	1951-49350	33.5	20	1	yes	no
CH-05-08	1951-49351	26.7	12	1	yes	attachment
CH-05-08	1951-49351	40.1	20	1	yes	yes
CH-05-84	1951-49352	21.8	12	1	yes	attachment
CH-05-84	1951-49352	36.0	20	1	yes	yes
CH-05-84	1951-49352	35.1	22	1	yes	yes
CH-05-07	1951-49353	18.0	7	2	no	
CH-05-07	1951-49353	33.0	15	2	no	
CH-05-07	1951-49353	35.5	17	2	no	
CH-05-07	1951-49354	17.0	7	2	no	
CH-05-07	1951-49354	34.2	15	2	no	

Nest no.	Band no.	Mass (g)	Age (days)	Age accuracy[1]	Radioed[2]	Radio status[3]
CH-05-07	1951-49354	35.8	17	2	no	
CH-05-07	1951-49355	16.0	7	2	yes	attachment
CH-05-07	1951-49355	29.9	15	2	yes	yes
CH-05-07	1951-49355	32.9	17	2	yes	yes
CH-05-07	1951-49356	12.8	7	2	yes	attachment
CH-05-07	1951-49356	27.4	15	2	yes	yes
CH-05-07	1951-49356	29.2	17	2	yes	yes
CH-05-58	1951-49359	21.2	11	3	will	
CH-05-58	1951-49359	35.0	19	3	yes	attachment
CH-05-58	1951-49359	38.1	24	3	yes	yes
CH-05-58	1951-49360	19.2	11	3	yes	attachment
CH-05-60	1951-49361	16.2	7	4	will	
CH-05-60	1951-49361	31.6	15	4	yes	attachment
CH-05-60	1951-49361	40.0	23	4	yes	no
CH-05-60	1951-49362	15.7	7	4	yes	attachment
CH-05-60	1951-49362	30.3	15	4	yes	no
CH-05-92	1951-49366	20.3	12	3	yes	attachment
CH-05-92	1951-49366	24.3	14	3	yes	yes
CH-05-92	1951-49366	26.2	16	3	yes	yes
CH-05-45	1951-49367	18.0	12	1	yes	attachment
CH-05-45	1951-49367	27.1	18	1	yes	yes
CH-05-45	1951-49367	27.2	20	1	yes	yes
CH-05-45	1951-49367	34.4	23	1	yes	yes
CH-05-73	1951-49374	12.6	8	1	yes	attachment
CH-05-73	1951-49374	33.7	19	1	yes	no
CH-05-90	1951-49375	10.7	6	1	no	
CH-05-90	1951-49376	13.1	6	1	yes	attachment
CH-05-90	1951-49376	21.7	10	1	yes	yes
CH-05-90	1951-49377	10.9	6	1	no	
CH-05-112	1951-49386	5.7	1	3	no	
CH-05-112	1951-49387	5.6	1	3	no	
CH-05-68	1951-49390	18.0	9	3	no	
CH-05-68	1951-49391	19.5	9	3	yes	attachment
CH-05-68	1951-49391	32.3	17	3	yes	yes
CH-05-71	1951-49392	6.0	1	3	no	
CH-05-71	1951-49393	7.0	1	3	no	
CH-05-71	1951-49394	7.5	1	3	no	
CH-05-60	1951-49395	17.2	15	4	yes	attachment
CH-05-93	1951-49397	22.2	10	1	no	
CH-05-93	1951-49398	22.2	10	1	no	
CH-05-93	1951-49399	21.7	10	1	yes	attachment
CH-05-93	1951-49400	20.0	10	1	yes	attachment
CH-05-83	2231-00201	6.5	4	1	will	
CH-05-83	2231-00201	11.6	8	1	yes	attachment

Nest no.	Band no.	Mass (g)	Age (days)	Age accuracy[1]	Radioed[2]	Radio status[3]
CH-05-72	2231-00202	24.6	12	2	yes	attachment
CH-05-73	2231-00204	35.4	19	1	no	
CH-05-73	2231-00205	32.4	19	1	no	
CH-05-88	2231-00208	21.0	10	1	no	
CH-05-86	2231-00209	6.0	2	1	no	
CH-05-86	2231-00210	6.3	2	1	no	
CH-05-120	2231-00212	6.1	2	1	no	
CH-05-120	2231-00213	7.1	2	1	no	
CH-05-124	2231-00217	5.3	4	1	no	
CH-05-124	2231-00218	6.0	4	1	no	
CH-05-108	2231-00219	8.7	4	3	no	
CH-05-108	2231-00220	8.6	4	3	no	
CH-05-19	991-08048	5.3	4	2	no	
CH-05-19	991-08048	11.7	12	2	no	
CH-05-19	991-08048	23.9	18	2	no	
CH-05-19	991-08049	5.1	4	2	no	
CH-05-19	991-08050	5.3	4	2	will	
CH-05-19	991-08050	10.9	12	2	yes	attachment
CH-05-19	991-08050	22.6	18	2	yes	yes
CH-05-79	991-08051	5.7	6	4	no	
CH-05-79	991-08051	30.4	24	4	no	
CH-05-79	991-08052	6.0	6	4	will	
CH-05-79	991-08052	16.6	16	4	yes	attachment
CH-05-79	991-08052	21.6	18	4	yes	yes
CH-05-79	991-08052	30.4	24	4	yes	yes
CH-05-79	991-08053	5.3	6	4	no	
CH-05-80	991-08054	6.3	6	4	no	
CH-05-80	991-08055	6.6	6	4	no	
CH-05-80	991-08056	6.7	6	4	no	
CH-05-80	991-08057	6.4	6	4	no	
CH-05-66	991-08058	7.1	5	4	will	
CH-05-66	991-08058	14.9	11	4	yes	attachment
CH-05-66	991-08058	31.6	23	4	yes	yes
CH-05-66	991-08059	7.7	5	4	no	
CH-05-66	991-08059	16.8	11	4	no	
CH-05-66	991-08059	35.7	23	4	no	
CH-05-27	991-08064	7.9	3	1	will	
CH-05-27	991-08064	19.5	12	1	yes	attachment
CH-05-27	991-08064	26.9	16	1	yes	yes
CH-05-27	991-08065	7.4	3	1	no	
CH-05-27	991-08065	15.5	12	1	no	
CH-05-27	991-08065	22.1	16	1	no	
CH-05-27	991-08066	8.1	3	1	will	
CH-05-27	991-08066	18.2	12	1	yes	attachment

Nest no.	Band no.	Mass (g)	Age (days)	Age accuracy[1]	Radioed[2]	Radio status[3]
CH-05-27	991-08066	26.9	16	1	yes	yes
CH-05-24	991-08067	8.0	4	3	will	
CH-05-24	991-08067	18.7	13	3	yes	attachment
CH-05-24	991-08068	7.2	4	3	will	
CH-05-24	991-08068	19.8	13	3	will	
CH-05-24	991-08068	31.0	19	3	yes	attachment
CH-05-24	991-08069	6.0	4	3	no	
CH-05-16	991-08070	8.1	3	2	will	
CH-05-16	991-08070	14.6	9	2	yes	attachment
CH-05-16	991-08070	20.0	11	2	yes	yes
CH-05-16	991-08070	23.3	13	2	yes	yes
CH-05-16	991-08070	28.6	17	2	yes	yes
CH-05-16	991-08071	8.9	3	2	no	
CH-05-16	991-08071	15.0	9	2	no	
CH-05-16	991-08072	8.8	3	2	no	
CH-05-16	991-08072	13.9	9	2	no	
CH-05-67	991-08075	6.3	0	1	no	
CH-05-67	991-08076	6.1	0	1	no	
CH-05-67	991-08077	6.6	0	1	will	
CH-05-67	991-08077	25.5	21	1	yes	attachment
CH-05-67	991-08078	5.7	0	1	no	
CH-05-67	991-08078	17.9	21	1	no	
CH-05-33	991-08079	11.5	9	3	yes	attachment
CH-05-33	991-08079	16.4	11	3	yes	yes
CH-05-33	991-08080	10.4	9	3	no	
CH-05-33	991-08080	14.7	11	3	no	
CH-05-33	991-08081	10.3	9	3	no	
CH-05-33	991-08081	14.4	11	3	no	
CH-05-33	991-08081	24.9	17	3	no	
CH-05-76	991-08082	25.5	12	3	no	
CH-05-76	991-08083	24.0	12	3	no	
CH-05-76	991-08083	39.6	20	3	no	
CH-05-76	991-08084	25.8	12	3	no	
CH-05-76	991-08084	40.7	20	3	no	
CH-05-76	991-08085	25.1	12	3	yes	attachment
CH-05-76	991-08085	40.2	20	3	yes	yes
CH-05-54[4]	991-08086	10.9	8	1	yes	attachment
CH-05-54[4]	991-08086	27.5	16	1	yes	yes
CH-05-54[4]	991-08086	41.9	25	1	yes	no
CH-05-54[4]	991-08087	18.8	8	1	no	
CH-05-54[4]	991-08087	35.7	16	1	no	
CH-05-28	991-08091	25.5	12	3	no	
CH-05-28	991-08091	38.3	20	3	no	
CH-05-28	991-08092	21.5	12	3	no	

Nest no.	Band no.	Mass (g)	Age (days)	Age accuracy[1]	Radioed[2]	Radio status[3]
CH-05-28	991-08093	24.0	12	3	yes	attachment
CH-05-28	991-08094	23.5	12	3	yes	attachment
CH-05-30	991-08095	22.2	11	1	yes	attachment
CH-05-30	991-08095	33.7	19	1	yes	yes
CH-05-30	991-08096	23.6	11	1	no	
CH-05-30	991-08097	22.1	11	1	yes	attachment
CH-05-30	991-08097	35.6	19	1	yes	yes
CH-05-29	991-08098	20.1	11	1	no	
CH-05-29	991-08099	20.9	11	1	no	
CH-05-29	991-08100	18.2	11	1	yes	attachment
CH-05-29	991-08100	31.9	19	1	yes	yes
CH-05-29	991-08100	43.9	37	1	yes	no

[1] Hatch date determined by: (1) observed hatch; (2) egg laying or flotation estimate; (3) day before chick discovery when visits <5 days apart; (4) midpoint date when visits >5 days apart.

[2] Documents at which age chicks have radios attached. 'Will' describes visits where chicks were weighed before having a radio transmitter attached.

[3] Documents radio attachment age and attachment status at each visit.

[4] Unsure if chicks from CH-05-54 are from the same brood as masses were very different at first capture.