

Conservation Biology of Piping Plovers at Lake Diefenbaker, Saskatchewan

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1997 Progress Report

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Executive Summary

Piping plover (*Charadrius melodus*) populations have undergone a considerable decline since European settlement and, hence, are an endangered species in Canada (Goossen 1990b). Piping plovers are subjected to a host of anthropogenic disturbances which may limit their productivity. An understanding of site-specific disturbances which limit piping plover productivity, along with management plans that decrease these disturbances, are urgently needed. Lake Diefenbaker, a large reservoir in southern Saskatchewan, frequently hosts one of the largest concentrations of breeding piping plovers in North America (Haig and Plissner 1992). However, piping plover productivity at this important breeding site is generally poor (Espie et al. 1996). In some years, water supply operations that cause a rise in lake levels, and subsequent flooding of nests and decreases in brood-rearing habitat availability, have been suggested as being the limiting factor (Espie et al. *in press*, Skeel 1997).

In 1997, we commenced a multi-objective study of piping plover conservation biology at Lake Diefenbaker. Our goal was to ensure a stable piping plover breeding population at Lake Diefenbaker, which will enhance regional piping plover metapopulation viability, and hence, contribute to Canadian and American population recovery goals for this species. Our specific objectives for this study are to:

- 1) document long-term piping plover productivity at Lake Diefenbaker and determine whether this is a source or sink population.
- 2) develop a population-hydrological model which will predict piping plover habitat availability and productivity given actual or predicted water levels.
- 3) pursue water management scenarios which will soften the negative impact of rising reservoir water levels on piping plover reproductive success.
- 4) identify conservation measures which will mitigate effects of the current water management regime and to test at least one such measure.
- 5) develop management recommendations which will aid managers in maintaining or increasing piping plover productivity suitable for a growing population, while also meeting reservoir management goals.

Herein, we document the findings of our initial year of study and provide preliminary management recommendations. During the initial field season, with the help of volunteers, we conducted a complete census of piping plovers at Lake Diefenbaker (Thomson Arm, Gordon

McKenzie Arm and west to the Riverhurst ferry crossing) and counted 117 adults. We closely monitored 53 nests until their outcome was determined. We collected habitat availability data, and experimented with a nest translocation procedure using an artificial nest platform. Additionally, following Espie et al. (*in press*), we constructed a simple simulation model to predict, historically, the annual piping plover productivity at Lake Diefenbaker.

Piping plover productivity at Lake Diefenbaker in 1997 was poor. Only 20 of 46 "first" nests successfully hatched chicks. Clutch losses were due to nest flooding ($n = 15$) and predation ($n = 10$). Furthermore, 76 chicks were hatched but only 15 successfully fledged, resulting in a low productivity value of 0.32 chicks fledged per pair at Lake Diefenbaker (population stability is estimated at 1.13 chicks fledged per pair [Ryan et al. 1993]). No eggs hatched from re-nests ($n = 7$). We attribute poor piping plover productivity at Lake Diefenbaker in 1997 to a major reduction in nesting and brood-rearing habitat availability through the breeding season and predation. Habitat reductions on nesting beaches was in the order of 90%.

Our nest translocation experiments demonstrated the general usefulness of this technique, as all seven pairs subjected to the procedure accepted the artificial nest platforms and, in most cases, found the new clutch location. However, our nest translocation experiment underscored the need for protection of brood-rearing habitat availability.

We constructed a preliminary stochastic simulation model of piping plover productivity for this site. Our model, both improves upon and confirms an earlier modeling efforts by Espie et al. (*in press*) for piping plovers at Lake Diefenbaker. The model predicts that in only eight of the 29 years modeled (1969-1997) piping plovers at Lake Diefenbaker attained productivity values at, or above, the population stability level. Thus, modeling of the Lake Diefenbaker population suggest that this breeding site is a population sink. Initial analysis of the model's fit to actual productivity for a small proportion of the years included, suggests that the model is an accurate representation of the population dynamics at this important breeding site. The model was constructed in a manner conducive to statistical and sensitivity analysis (currently underway) that will evaluate and rank productivity enhancement strategies.

Our primary management recommendation is the development of water supply operation protocols that would ensure an adequate breeding habitat for piping plovers at Lake Diefenbaker. Preliminary investigations suggest that, in most years, modest reductions in reservoir filling rates may result in substantial increases in piping plover productivity. Other recommendations include artificial nest translocation, nest exclosures and reducing human disturbance.

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1.0 Introduction

The piping plover (*Charadrius melodus*) is a small, migratory shorebird which has undergone a considerable population decline since European settlement. As such, the piping plover has been listed as endangered in Canada and the American Great Lakes, and threatened elsewhere in the United States (*sensu* Haig 1992). Ryan et al. (1993) modelled the metapopulation viability for this species and estimated that the Great Plains piping plover population was declining in the order of 7% per annum. Their model demonstrated that small delays in stabilizing the population would significantly increase the number of years required to raise the population to established recovery goal levels. The implications of Ryan et al. (1993) are clear; immediate action is required to halt the decline of piping plover populations.

Implementing population recovery, however, is difficult because piping plovers nest in a variety of beach habitats, which are each subjected to varying types and levels of anthropogenic disturbances. As such, the ability to plan effective conservation strategies are severely hampered by a lack of site-specific knowledge of the factors limiting population growth.

Both the 1991 and 1996 international Piping Plover censuses identified Lake Diefenbaker, in southern Saskatchewan, as hosting one of the largest continental breeding populations, representing up to 19% of the Canadian prairies population and 5% of the total North American population (Haig and Plissner 1992, Skeel et al. 1997). However, dynamic changes in water levels at Lake Diefenbaker may produce both attractive and fatal consequences for piping plovers. Winter drawdown of the reservoir results in wide beach habitats which provide attractive nesting habitat to piping plovers arriving in the spring. Water levels rise throughout the spring with input flows originating from the Rocky Mountains and output flows controlled by two dams. Rising water levels at Lake Diefenbaker often encroach upon piping plover nesting and brood-rearing habitats (Espie et al. *in press*). Fluctuating water levels, in some years, have a deleterious impact on piping plover reproductive success, as a large proportion of habitat is flooded (Skeel 1997). Lake Diefenbaker may act as an ecological trap by initially attracting piping plovers, but at times, later destroying their breeding efforts through extensive nest and habitat flooding. Furthermore, given the number of birds that nest at Lake Diefenbaker, low productivity values at this site may have a

detrimental effect on metapopulation viability.

Piping plover population recovery largely depends on accurate population assessments through continuous monitoring of breeding populations (Goossen 1990a, 1990b, Goossen et al. *in prep.*). We conducted a breeding pair survey of piping plovers at Lake Diefenbaker during the 1997 breeding season and compared this value with that of previous population censuses. The objectives of the population census were (1) to estimate the current piping plover population size and (2) to determine spatial distributions of piping plover habitat use.

We investigated the nesting chronology and productivity of the Lake Diefenbaker piping plover population. The objectives of this portion of the study were (1) to document nesting chronology, (2) to measure hatching and fledging rates, (3) to measure habitat characteristics, 4) to compare the above data with water supply operations and 5) to identify factors limiting piping plover productivity. Breeding biology and productivity data were collected to permit detailed modeling of the problem, in an effort to find a workable solution.

Haig and Plissner (1992) report that in 1991, 18.2% of the Northern Great Plains/Prairies piping plovers were associated with reservoir beaches. Reservoirs are generally unreliable piping plover nesting areas because dynamic changes in water levels can flood nests (Espie et al. *in press.*, Espie et al. 1996, North 1986, Prellwitz et al. 1989, Schwalbach 1988, Sidle et al. 1992). As such, wildlife managers are currently seeking remedial actions to increase piping plover productivity, where threatened by nest flooding. Nest translocation is one potential technique for offsetting the impact of nest flooding on piping plover productivity (Prellwitz et al. 1995). However, a quantitative assessment of the efficacy and response by incubating pairs to this technique has not been undertaken. Our objectives of this portion of the study were (1) to assess the feasibility of nest translocation as a remedial action to enhance piping plover productivity and (2) to elicit the relationships between piping plover nest finding abilities and (a) distance the nest was moved, (b) number of times the nest was moved, and c) differential response by pairs.

If piping plover productivity at Lake Diefenbaker is frequently below the population stability level as suggested by Skeel (1997) and Espie et al. (*in press*), then the question becomes is this a

sink population, and if so, what conservation strategies can be pursued to increase piping plover productivity? To answer these important questions we undertook a stochastic simulation modeling exercise. We built a simple rule-enhanced model (Starfield and Bleloch 1991), conceptually similar to an earlier model constructed by Espie et al. (*in press*) used to examine the historical productivity of piping plovers at this site. Our objectives were 1) to refine and test the accuracy of the model developed by Espie et al. (*in press*) by assessing the historical productivity of piping plovers at Lake Diefenbaker, and 2) to provide an accurate model which can then be used to a) explore productivity - water supply operation relationships, through examination of the sensitivity of model output to simulated input parameters, and b) design effective piping plover management strategies at Lake Diefenbaker.

2.0 Study Area

Lake Diefenbaker (51° 10'N, 106° 50'W), located on the South Saskatchewan River in southern Saskatchewan (Figure 1), is one of North America's largest managed reservoirs. The lake has approximately 225 km of linear shoreline habitat, encompassing more than 43,000 hectares at full supply. We confined our study area to the Thomson and Gordon McKenzie arms and beaches west to the Riverhurst ferry crossing. Lake Diefenbaker was created to capture and store spring runoff into the South Saskatchewan River by the construction of two dams. Annual inflows to the reservoir vary considerably, and are dependent upon winter precipitation in the eastern Rocky Mountains and, to a lesser extent, the southwestern prairies (Environment Canada *unpubl. data*). Since the reservoir's inauguration in 1967, the Saskatchewan Water Corporation mandate is to manage the lake for multi-purpose use including hydro-electricity (Saskatchewan Power Corporation), municipal water supply, irrigation, recreation, and wildlife habitat. Several small communities and three provincial parks are located around the lake. Land use adjacent to the lake is predominately agricultural, and includes pasture, crops, and woodlots. Climate is typical of the Northern Great Plains and the Canadian prairies.

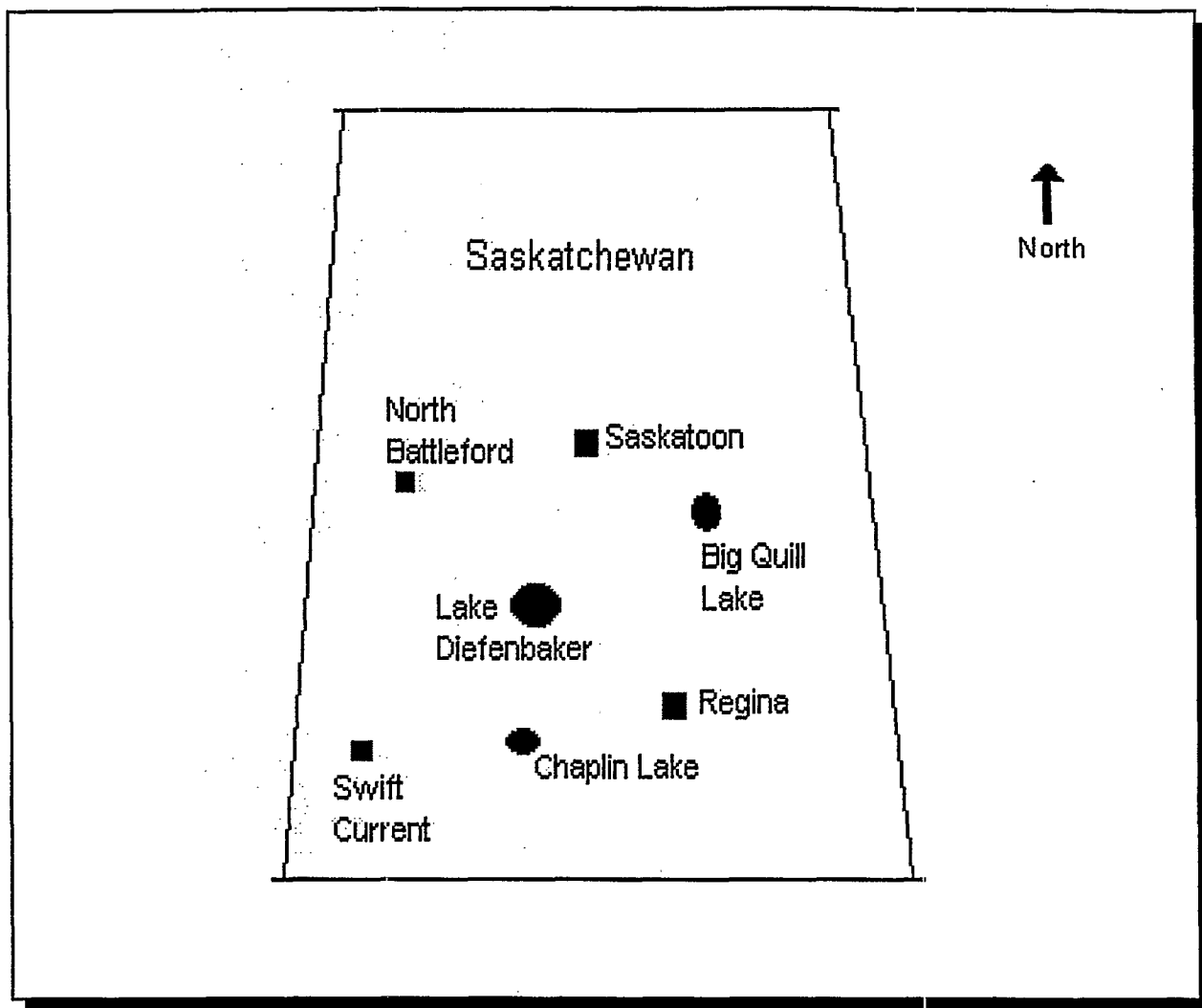


Figure 1. Location of major piping plover breeding sites in Saskatchewan. (Not to scale).

3.0 Methods

3.1 Population Census

Census Protocol

We conducted a piping plover breeding pair survey at Lake Diefenbaker from 2 - 6 June 1997. The habitat and behaviour of the piping plover make it a conspicuous bird, readily counted, despite its cryptic colouration. We followed the piping plover survey protocol of Goossen (1990a). We surveyed all of the beaches to both dams, and west to the ferry crossing near Riverhurst (Figure 2) were surveyed. Our survey was aided, in part, by *a priori* knowledge of where most piping plovers were on the lake, as we had initiated the field study of piping plover breeding ecology one month prior to the June census period.

Depending on the accessibility, quantity and quality of piping plover beach habitat, we used three different search techniques (Figure 2). Shorelines with wide beaches (>75 m wide) were searched by two or more observers walking 50-100 m apart, parallel to the water's edge, while relatively narrow beaches (50-75 m) were searched by one person riding an All Terrain Vehicle (ATV) parallel to the lakeshore. For beaches difficult to access from land, we used a boat with four people to scan shorelines and physically search an area. We went ashore to search where we knew piping plovers were nesting, where we observed a piping plover or where the beach was too large to carefully search from the boat. Observers used binoculars and/or spotting scopes to locate and identify piping plovers.

Observers determined piping plover breeding status by observing behavioural cues (Cairns 1982) and assigning one of the following status designations to each bird: pair, territorial single, or non-territorial single. Where a pair was suspected to be breeding, we endeavoured to locate both adults and their nest. The approximate location of nests, number of birds and reproductive status were mapped on 1:50,000 topographic maps.

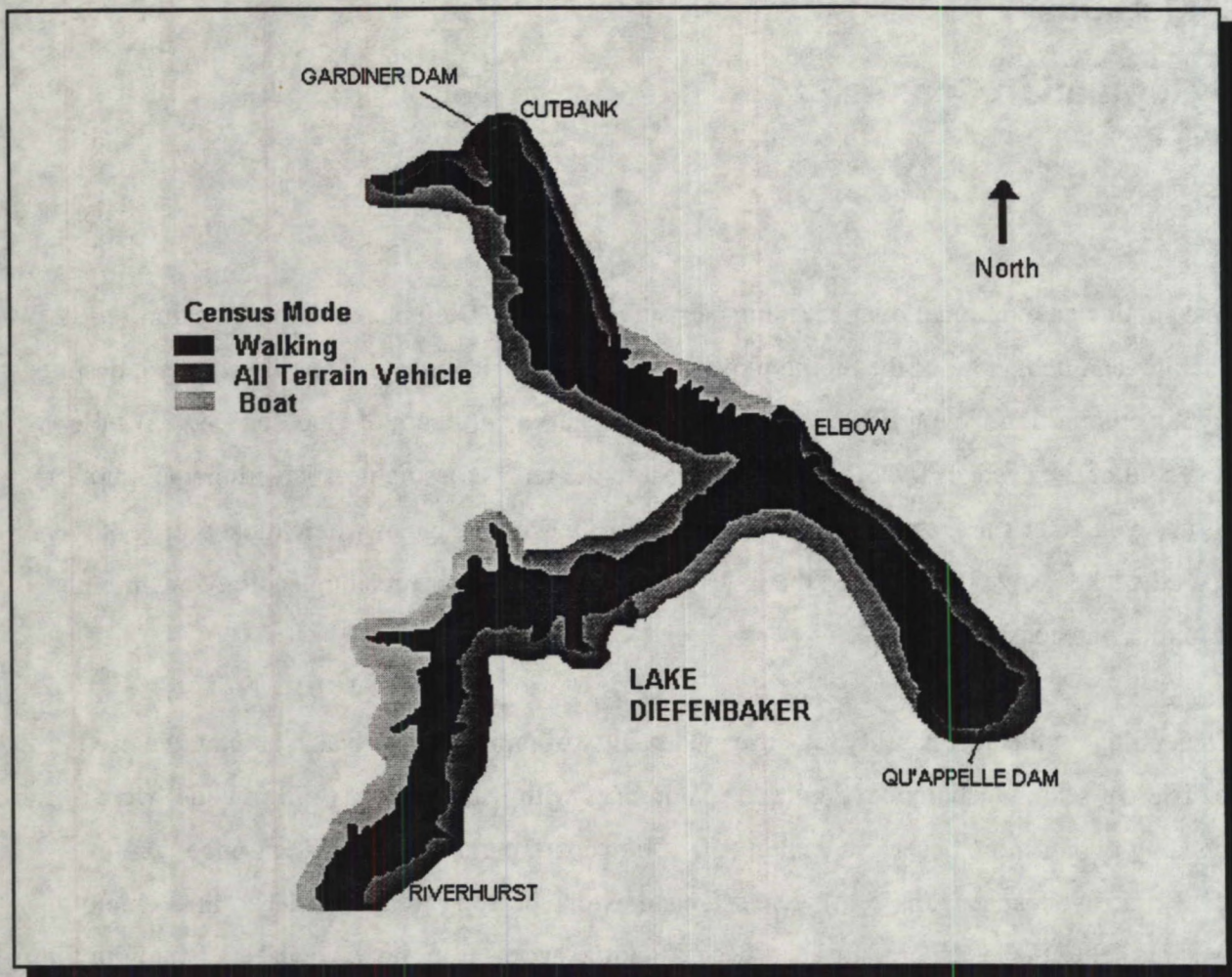


Figure 2. Stylized map of Lake Diefenbaker with 1997 census travel modes. (Not to scale).

Data Analysis

We used the number of pairs observed, plus the number of territorial singles seen, to estimate the number of breeding pairs present at Lake Diefenbaker. We compared the estimated 1997 population size with those from previous years (data obtained from Skeel 1997). We acknowledge that direct comparisons between annual censuses is difficult because of annual variations in census protocols. At Lake Diefenbaker, various portions of the lake have been surveyed from year to year (Skeel 1997), with census intensities and proportion of habitat surveyed being limited to logistics and funding within each year. Nonetheless, surveys are a useful indicator of the relative magnitude of population changes.

3.2 Nesting Biology and Productivity

Clutch Fate

Between 5 May and 9 June, we systematically searched the entire shoreline of the Lake Diefenbaker study area for nesting piping plovers. We transversed beaches by walking and, in some areas, with the use of ATVs. Most beaches were checked, at least twice, for territorial piping plovers. Suspected re-nests were located later during nest monitoring. Where nesting activities were suspected, we located nest sites by observing, from a distance, territorial adults (Cairns 1982) until they returned to the nest. Nests were marked with a tongue depressor placed about 5 m from the nest bowl, and a larger wooden shim placed approximately 10 m from the tongue depressor. In some instances, rock cairns were placed near the vegetation line at a distance of ≥ 30 m, to locate nests on expansive, homogenous beaches. To further facilitate relocating nests, we obtained universal transverse mercator (UTM) coordinates for each nest site with a hand held global positioning system (GPS) unit. Nests were monitored periodically (1-3 visits per week) until their outcome was determined. At each visit, we recorded the number of adults and eggs present at each nest. Generally, we conducted all observations in less than five minutes in order to minimize researcher-associated disturbance and biases to the data set (MacIvor et al. 1990).

Clutch fates were categorized into four classes: 1) predated, 2) flooded, 3) abandoned, and 4) successful. A nest was considered predated when the nest bowl was not flooded and all the eggs were missing before the expected hatch date. Nests were categorized as flooded when we observed that the nest site under water before the expected hatch date. We classified nests as abandoned when we observed eggs in the nest, but with no incubating adults seen over the course of three consecutive visits, and the eggs were cold to the touch. Windblown sand accumulations in the nest bowl provided further evidence of abandonment, as piping plovers, typically, keep their nests free of such deposits (Cairn 1982). We defined a nest as successful when one or more eggs hatched (Patterson et al. 1991, Prindiville Gaines and Ryan 1988). Mayfield nest success estimates were calculated (Mayfield 1975, Miller and Johnson 1978). Only "first nests" were used for chronology, clutch size, clutch fate and reproductive success parameters. Additionally, where available, we collected eggs that did not hatch, due to nest flooding and abandonment, or they failed to hatch. Collected eggs were sent to the Canadian Cooperative Wildlife Health Centre in Saskatoon for analysis (see Appendix 1).

Nest Chronology

To determine clutch initiation dates, we visited nests found with partial clutches about every 1-2 days until a full clutch was observed. Nests found with a full clutch were dated using the egg flotation technique (Schwalbach 1988, Hayes and LeCroy 1971). Hatch dates were estimated as 34 days after the first egg was laid (Haig 1992, Prindiville Gaines and Ryan 1988, Whyte 1985). Upon the approach of the estimated hatch date of each nest, we visited the nest everyday to record the hatch date. We verified, and in some instances, revised our clutch initiation dates with known hatching dates. All chicks surviving 25 days after the hatch date were classified as fledged (Haig 1992).

Chick Survival

We monitored nests during the hatching period, and recorded the number of chicks hatched at each nest. At some beaches with multiple broods, chicks were captured by hand and colour-banded in order to identify individual broods. Broods were monitored approximately every three days,

from a minimum distance of 25 m, until they dispersed. In cases where we observed fewer chicks than during our previous visit, one to two people systematically searched the nesting area and adjacent beach. Major decreases in brood-rearing habitat, coupled with an increase in the isolation of beaches, simplified the process of locating broods. Nests were considered to successfully fledge young when one or more chicks survived 25 days after hatching (Haig 1992). Chick survival was assessed for 5-day intervals, from hatch to fledge dates.

Habitat Availability and Beach Topography

At each nest site, we measured the beach width from the nest to the lakeshore and to the vegetation line. We did this when the nest was found and once a week thereafter, to determine changes in brood-rearing habitat availability. To assess the impact of temporal changes in habitat availability on productivity, we analysed the proportional difference in beach width at each nest and brood-rearing area over the course of the breeding season, and compared these figures with nest fate, chick survival rates, and productivity.

We used a laser transit (Nikon DTM-A5LG Total Station Transit) to measure nest elevation, and the width and area of known nesting beaches. Nest site elevation was calculated by adding these values with daily water levels provided by the Saskatchewan Water Corporation. We were interested in both the width and area of six selected nesting beaches at different water levels. To assess these relationships, in 1996 and 1997, we used four to five variable length transects and measured 90 or more points with a laser transit. These data were then used to generate cross sections of each beach, at the given water levels on the day of the survey, using Quicksurf and AutoCad software. We used the software programs to calculate the beach width and area available at given water levels.

3.3 Artificial Nest Translocation

Nest Selection

We moved eight different clutches at various nesting beaches at Lake Diefenbaker. An artificial

nest platform was used for seven clutches and in one case nest scrapes were made by hand. We selected clutches to be moved by how vulnerable they were to being flooded, before their anticipated hatch date. Estimated flood dates were determined by known nest elevation (measured with a laser transit), the known reservoir level, and the forecasted daily water level rise provided by the Saskatchewan Water Corporation. Estimated hatch dates were derived from egg flotation (Schwalbach 1988, Hayes and LeCroy 1971), and in some cases, from observation of the egg-laying sequence. Similar to Hjertaas (1997) and Prellwitz et al. (1995), all of the clutches chosen were clearly in danger of flooding. Due to rising water levels at Lake Diefenbaker throughout the incubation period, distance between the nest site and the lakeshore was greatly reduced, and all clutches were within 10 m of the lake prior to clutch translocations.

Nest Platform Construction

Our protocol differed from that of Hjertaas (1997) and Prellwitz et al. (1995) in that we fabricated an artificial nest on a platform. We used a plastic container (approx. 30 cm in diameter and 5 cm deep) to hold the new nest bowl. We drilled several small holes in the bottom of the container to allow precipitation to pass through the nest, preventing nest flooding from within the container. We filled the container with sand and created a new nest site typical of actual piping plover nests observed at Lake Diefenbaker (a pebble-lined depression with the approximate dimensions of 10 cm in diameter and 2 cm deep). We prepared the artificial nest on site, but at a minimum distance of 50 m from the nesting pair so as to minimize disturbance. The artificial nest was easily created in less than 20 minutes.

Artificial Nest Translocation

With the artificial nest prepared, eggs were transferred from the nest to a temporary holding container (a poultry egg carton), and the artificial nest was installed flush with the beach substrate. We filled the previous nest location with sand and rocks and transferred the eggs to the artificial nest platform. For each translocation, we measured the time required to move the clutch, the distance from the previous clutch location to the new clutch location, the time required by one of the adults to locate the new clutch location, and general behavioural and weather observations.

MacIvor et al. (1990) reported that research activity, including egg handling, did not have a statistical effect on nest predation. Nonetheless, for most translocations, we removed excavated substrate material and attempted to clear our footprints before leaving the area, so as to negate any effect that our presence may have had in attracting potential nest predators. Generally, we performed a series of translocations on a specific clutch in a single day. We waited a minimum of 30 minutes between successive translocations of the same clutch. The first time we moved a specific clutch we installed the artificial nest platform approximately 1 m from the actual nest site. For subsequent translocations, we varied the distance between the nest sites, depending on 1) the urgency of the situation, 2) beach morphology near the nest site, and 3) our qualitative assessment of the adeptness of a specific pair at relocating the new clutch location. We defined a successful nest translocation as one in which at least one of the adults located the translocated clutch within 25 minutes. In the event that the pair had difficulty finding the new clutch location, we returned the clutch close to its previous location, waited a further 30 minutes, and then attempted to move the clutch again. We monitored all translocated clutches until their expected hatch dates to evaluate hatching success.

Data Analysis

We performed 52 clutch translocations on seven different clutches. One additional translocation was not included in the analysis. We used each nest translocation with a nest platform ($n = 41$) as an independent sample for statistical analysis. Failed nest translocation ($n = 2$ translocation) resulted in data outliers. These were removed from the data set to prevent gross skews in the data and allow the emergence of trends.

We examined variability in responses to clutch translocation among pairs by comparing the time required by each pair to locate translocated clutches, over repeated moves, with a non-parametric ANOVA (Sokal and Rohlf 1981). Linear regression was used to examine the relationship between the time required by adult piping plovers to locate the new clutch location relative to the distance the clutch was moved. Additionally, we were interested in knowing if the incubating pair became accustomed to the clutch translocation procedure with each subsequent translocation. We examined this relationship by plotting the mean time required for the pairs to

locate the translocated clutches as a function of the number of times the clutch was moved. Clutches were translocated a variable distance both with each translocation and among pairs, as such, we standardized our data by using the mean time required to locate the new clutch location per metre the clutch was moved. We tested this relationship using Kruskal-Wallis, with the move number (chronologically) as the grouping variable. Due to small sample sizes, we elected to use a significance value of $p > 0.10$ (Sokal and Rohlf 1981).

3.4 Population-hydrology Modeling

The Model, Parameter Estimation, and Assumptions

We followed a conceptually simple modeling approach to assess piping plover productivity and hydrology relationships at Lake Diefenbaker, and to provide a basis for evaluating productivity enhancement strategies at this site through simulation modeling (Starfield 1997). Our model followed that of Espie et al. (*in press*), but deviated from their model in objectives and parameter estimation, however, the general protocol for both models is very similar. We simulated the number of chicks fledged from each nest for any given year. We assumed that piping plover productivity at Lake Diefenbaker, and possibly other reservoirs, is a function of the number of eggs lost to flooding and nest predation, and the number of chicks lost to both natural mortality (predation, exposure, etc.) and the potentially additive effect of diminishing brood-rearing habitat availability. The equation used for each simulated nest was as follows (from: Espie et al. *in press*):

$nf = ne - nef - nep - ncl - ncr$, where:

nf = number of fledglings produced for a given nest

ne = number of eggs (clutch size)

nef = number of eggs lost due to nest flooding

nep = number of eggs lost due to predation

ncl = number of chicks lost due to the natural chick mortality rate

ncr = number of chicks lost due to the additive effect of loss of brood-rearing habitat

We modeled the predicted piping plover productivity at Lake Diefenbaker for the years 1969 to

1997, using known lake levels on 1 May (arrival date of plovers) , 15 June (mean hatch date), and 15 July (mean fledge date), for each year in the model. We used a constant number of 45 nests for each year, and iterated the model five times for each year, resulting in a sample size of 225 nests per year. We strived to simplify our model so that the relevant relationships between productivity and the parameters could, later, be elicited through statistical and sensitivity analysis. To simplify the model, we made the assumptions that for each nest the clutch size was four eggs, and that clutches affected by flooding and nest predation lost all four eggs.

At Lake Diefenbaker, piping plover nest site elevations for each year vary, and are dependent on the lake level during the clutch initiation stage in early May. We used a one-way ANOVA to analyze the annual variation of nest elevations at Lake Diefenbaker and observed a significant difference among years (ANOVA, $p < 0.001$, $df = 3$, $n = 134$). To reduce potential biases created by the annual variation in nest site elevations, we calculated the height (m) of each nest above the 1 May water level for the year that the nest was measured. We used a sample of 134 nest elevations measured from 29 nests in 1991 (Robinson and Hjertaas 1991), 30 nests in 1992 and 37 nests in 1993 (Espie et al. *in press*) and 46 nests in 1997 (this study). We then randomly generated elevations above the 1 May water level for each nest in the model based on the frequency distribution of the 134 measured nests. Likewise, the value for the 15 July water level used in the model was the difference between the 15 July water level and the 1 May water level for each year. Flooding of a nest was assumed when the height of the nest above the 1 May water level was equal to, or less than, the difference between the 1 May water level and the 15 July water level for each given year.

We used a random number generator to assign a nest predation status (i.e. yes or no) based on a 20% probability that a nest would be predated. The probability value for a nest being predated was determined based on the observed nest predation rates of monitored nests at Lake Diefenbaker in 1992-1993 (Espie et al. 1996) and 1997. We considered each nest in the model hatched four chicks if the nest was not flooded nor predated.

Similar to Espie et al. (*in press*), our model distinguishes between natural chick mortality and additive chick mortality as brood-rearing habitat diminishes through flooding. Chick mortality

estimates, however, are unavailable from both the Lake Diefenbaker population, specifically and from the literature, generally. Furthermore, assessment of the specific causes of chick mortality, and separation of these from other possible contributing factors, are difficult to assess through field studies. With the available data from Lake Diefenbaker, we hypothesized that in 1992 adequate amounts of brood-rearing habitat were available and that all chick mortality in that year was natural, without the potentially synergistic effect of loss of brood-rearing habitat. As such, we used the observed 1992 chick mortality rate of 32% as our natural chick mortality rate for all nests that hatched chicks in the simulations.

For the purposes of our model, we assumed a linear relationship between the 15 July water level and additive chick mortality above the natural chick mortality rate. We proportionally modeled the additional loss of chicks based on the 15 July water level, where a 15 July water level of less than 555 m ASL (Above Sea Level) resulted in no additional loss of chicks, and as a consequence of a major loss of brood-rearing habitat, a 15 July water level of 556.51 m ASL or greater resulted in an additive chick mortality rate of 0.8. As such, our model used a slope of 0.2 to predict additive chick mortality rates attributed to flooding of brood-rearing habitat. Specifically, additive chick mortality was set at 0.2, 0.4, and 0.6 for years with 15 July water levels between 555.01-555.5 m ASL, 555.51-556 m ASL, and 556.01-556.5 m ASL, respectively.

Predicted piping plover productivity for each year was calculated for each iteration based on the number of chicks fledged divided by number of nests (a constant of 45 in the model). We report a mean predicted productivity value for each year based on the productivity estimates for each of the five iterations in each year. Thus, model output for each year is based on a relatively robust sample size of 225 nests.

Model Analysis

To date, model analysis is in the early stages. We examined the sensitivity of model output to changes in only one parameter, natural chick mortality. This parameter was chosen with the belief that our estimation of this parameter was overly optimistic and that it would, perhaps, have an influential impact on the fit of our model to observed values. For each run, in each year, we

examined the effect of natural chick mortality, at values of 0.32, 0.45 and 0.55, on the model output. A Pearson correlation was used to statistically examine the model output among the different values for natural chick mortality. We examined the fit of the model to observed productivity values for years in which a sample of nests were monitored until their outcome was determined (specifically, 1991 [Robinson and Hjertaas 1991], 1992 and 1993 [Espie et al. *in press*] and 1997 [this study]).

4.0 Results and Discussion

4.1 Population Census

In 1997, we observed a total of 117 piping plovers at Lake Diefenbaker during the census period. We observed 42 pairs, 8 territorial singles, and 17 non-territorial singles. Piping plovers were observed on many varied beaches of Lake Diefenbaker, but their abundance was unevenly distributed among the beaches at Lake Diefenbaker. Areas of semi-colonial behaviour, and relatively high concentrations, included Gardiner Peninsula, the Summit Creek Area, Danielson Beach Area, and Sage Bay Area (Figure 3).

The 117 piping plovers observed in 1997 was 60.7% greater than the 1996 count of 71 individuals. However, the 1997 count is below the average piping plover count of 148.0 adults observed at Lake Diefenbaker from 1984 to the present.

Following Skeel (1997), we plotted the historical population estimates of piping plovers at Lake Diefenbaker against the 12 May water levels (the mean nest initiation date at this site), and observed a negative relationship ($r^2 = -0.87$, $p = >0.05$). The population size for any given year was generally lower at higher 12 May water levels and vice versa (Figure 4). Reasons for this significant relationship are unclear, but are most likely related to the amount of suitable nesting habitat available to arriving piping plovers at given water levels. Population sizes at Lake Diefenbaker most likely follow the local drought-flood precipitation cycle, which creates a variable amount of beach habitat available to shorebirds among years. Additionally, an important

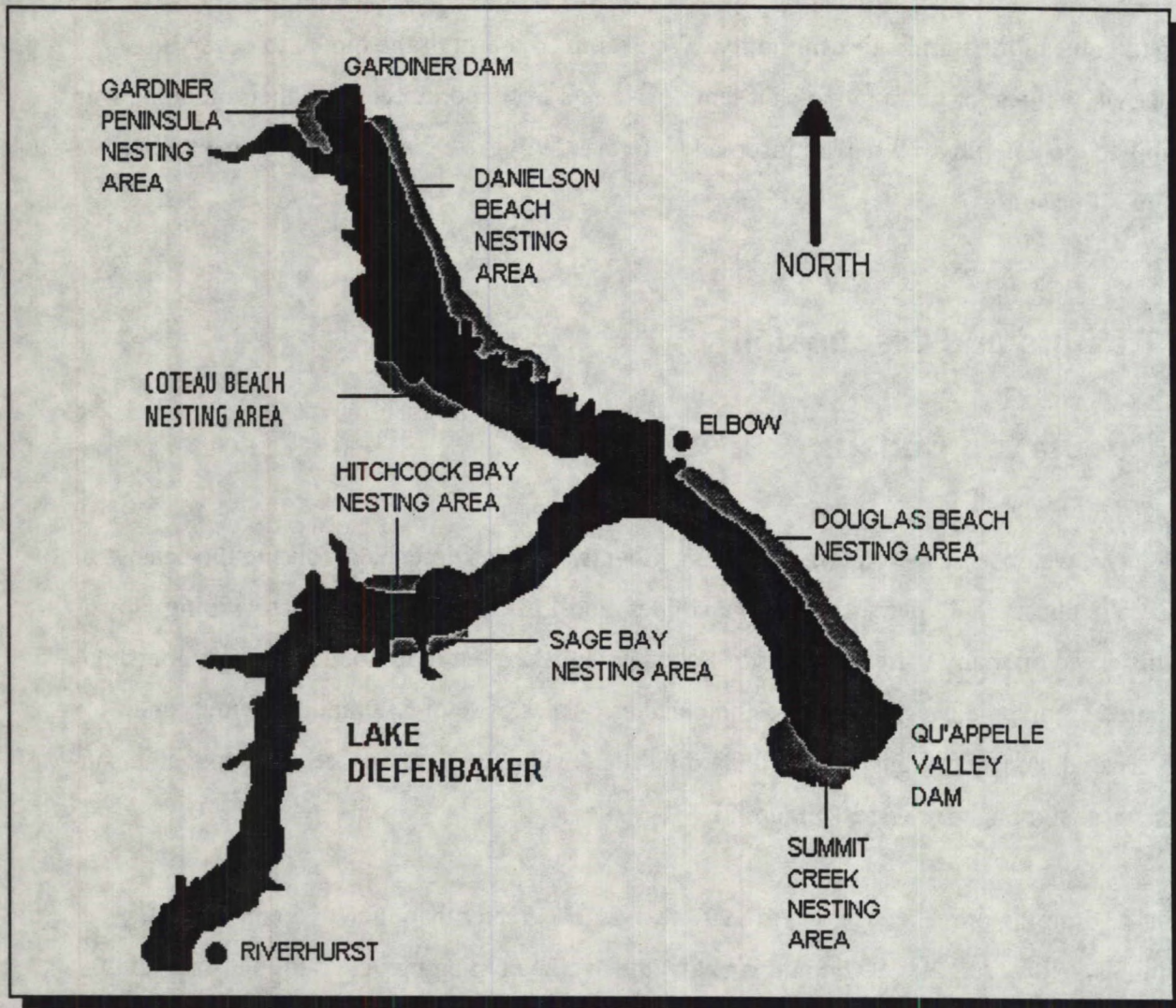


Figure 3. Stylized map of key piping plover nesting areas at Lake Diefenbaker in 1997 (Not to scale).

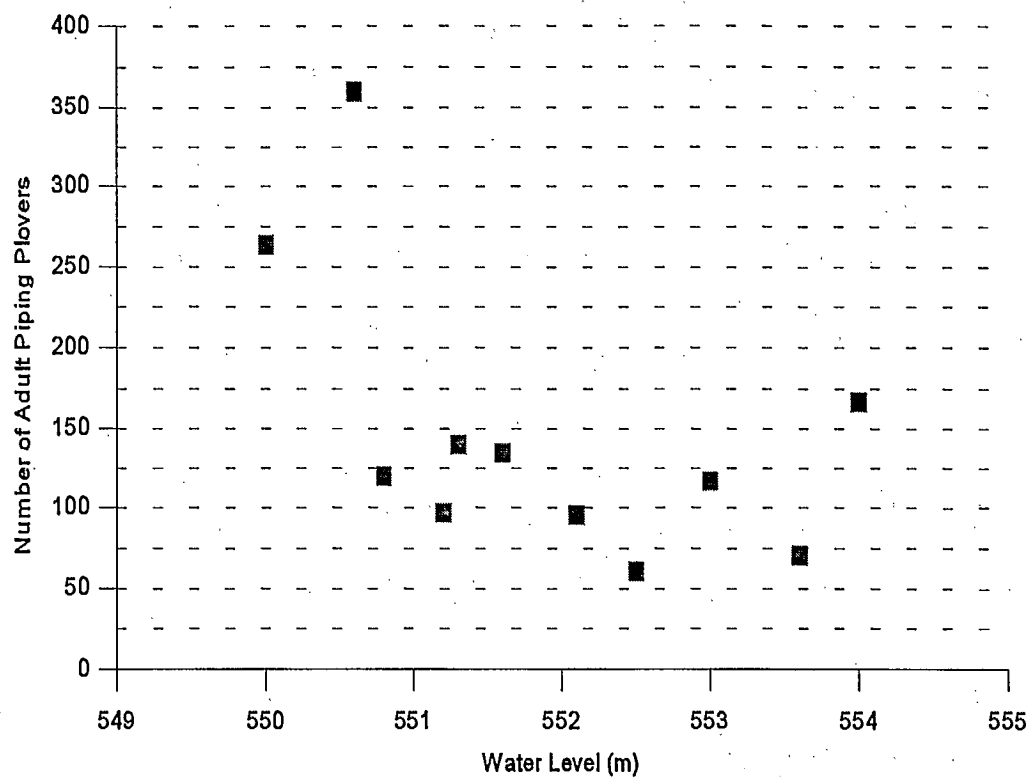


Figure 4. Relationship between piping plover population sizes at Lake Diefenbaker and the water level at the mean clutch initiation date (12 May). Modified from Skeel (1997).

interaction between the number of piping plovers at Lake Diefenbaker in any given year and the number of piping plovers at other sites in the Northern Great Plains may exist.

Few piping plover population censuses were carried out elsewhere in Saskatchewan in 1997. However, surveys were conducted at three other piping plover breeding sites - Chaplin Lake and Big Quill Lake (Figure 1), and Willow Bunch Lake. The former two sites have historically hosted large piping plover populations while the latter has recently shown an increase in piping plover numbers (Skeel et al. 1997, Haig and Plissner 1992, Harris and Lamont 1990). For 1997, the count of 117 individuals at Lake Diefenbaker was lower than the 124 adults counted at Willow Bunch Lake (E. Wiltse, pers. comm.), the 130 birds counted at Chaplin Lake (Jung et al. 1998 - see Appendix 3) and far less than the 427 birds observed at Big Quill Lake (Prairie Environmental Services 1998). Nonetheless, Lake Diefenbaker represented an important proportion of Saskatchewan's endangered piping plovers in 1997. The number of piping plovers estimated at Big Quill Lake have been steadily increasing since the 1991 International Piping Plover Census (W. Harris, *pers. comm.*), while those at Chaplin Lake have fluctuated considerably during the same period (Jung et al. 1998).

4.2 Nesting Biology and Productivity

Nesting Chronology and Clutch Size

Clutch initiation began as early as 6 May, with a mean clutch initiation date of 12 May (Table 1, Appendix 2). The mean hatch date was 15 June. Estimated fledge dates, calculated as 25 days after hatching dates, ranged from 3 July to 27 July (mean = 10 July). Our sample of 46 nests produced 181 eggs. Mean clutch size was 3.94 eggs (SD = 0.32, range = 3-4, n = 46).

We obtained a much larger sample size than in previous studies at Lake Diefenbaker, and our monitoring and methods were more rigorous (ie. egg flotation), nonetheless, our nesting chronology and clutch size values are similar to those presented elsewhere for Lake Diefenbaker (Table 1) and other Great Plains sites (Skeel 1997, Espie et al. 1996, Prindiville Gaines and Ryan 1988, Whyte 1985).

Table 1. Mean clutch initiation, hatching and fledging dates of piping plovers at Lake Diefenbaker, Saskatchewan. Ranges are given in parentheses. Modified from Skeel (1997).

YEAR	NUMBER OF NESTS	INITIATION DATE	HATCHING DATE	FLEDGING DATE
1991	13	MAY 15 (MAY 12 -29)	JUNE 17 (JUNE 14 -JULY 1)	JULY 12 (JULY 9 -26)
1992	22	MAY 12 (MAY 6 -JUNE 2)	JUNE 14 (JUNE 8 -JULY 5)	JULY 9 (JULY 3-30)
1993	9	MAY 8 (MAY 4-14)	JUNE 10 (JUNE 6-16)	JULY 5 (JULY 1-11)
1995	6	MAY 9 (MAY 7-14)	JUNE 11 (JUNE 9-16)	JULY 6 (JULY 4-11)
1996	5	MAY 20 (MAY 15 -29)	JUNE 22 (JUNE 17 -JULY 1)	JULY 17 (JULY 12-26)
1997	46	MAY 12 (MAY 6-31)	JUNE 15 (JUNE 8 -JULY 2)	JULY 10 (JULY 3 -27)

Clutch Fate

Less than half of the clutches (43.5%, $n = 20$) successfully produced one or more chicks. Nest flooding and predation caused the majority of nests to fail (Figure 5). The proportion of piping plover nests that hatched at Lake Diefenbaker in 1997 was higher than Espie et al. (1996) observed in 1993, but much lower than they observed for 1992 (Figure 6).

We calculated a Mayfield nest success estimate of 29.2% during the incubation stage. We attribute the large discrepancy in the Mayfield estimate and our observed value to the applicability of the Mayfield method to our data set. An assumption of the Mayfield method is that many nesting attempts are not observed (Mayfield 1975, Miller and Johnston 1978). In our study, intense surveys of nesting most likely permitted us to observe a large majority of nesting attempts, hence, resulting in an underestimation of nest success when using the Mayfield method.

Individual egg hatching rates were high (96.2%) in clutches that survived until their hatch date. A high probability of an individual egg hatching, combined with an average clutch size and only one case of nest abandonment, suggests that adults are in good physical condition and not limited by bioenergetic constraints (i.e. food availability) during the incubation period.

A substantial number of nests were depredated (21.7%, $n = 10$). The depredation rate on nests in our study is in accordance with that of other piping plover studies in the Great Plains (Espie et al. 1996, Prindiville Gaines and Ryan 1988, Whyte 1985). We predicted a positive relationship between the proportion of beach habitat flooded and predation rates, due to a decrease in search effort required by nest predators in finding nests. Curiously, the predation rate remained relatively constant over three years with very different rates of habitat flooding, suggesting no such relationship (Figure 6). Unfortunately, we were unable to determine specific nest predators in our study. However, gulls (*Larus* spp.) were numerous, and coyote (*Canis lupus*) tracks were frequent at most nesting areas. Both species have been implicated as piping plover nest predators in the Great Plains (Prindiville Gaines and Ryan 1988, Whyte 1985).

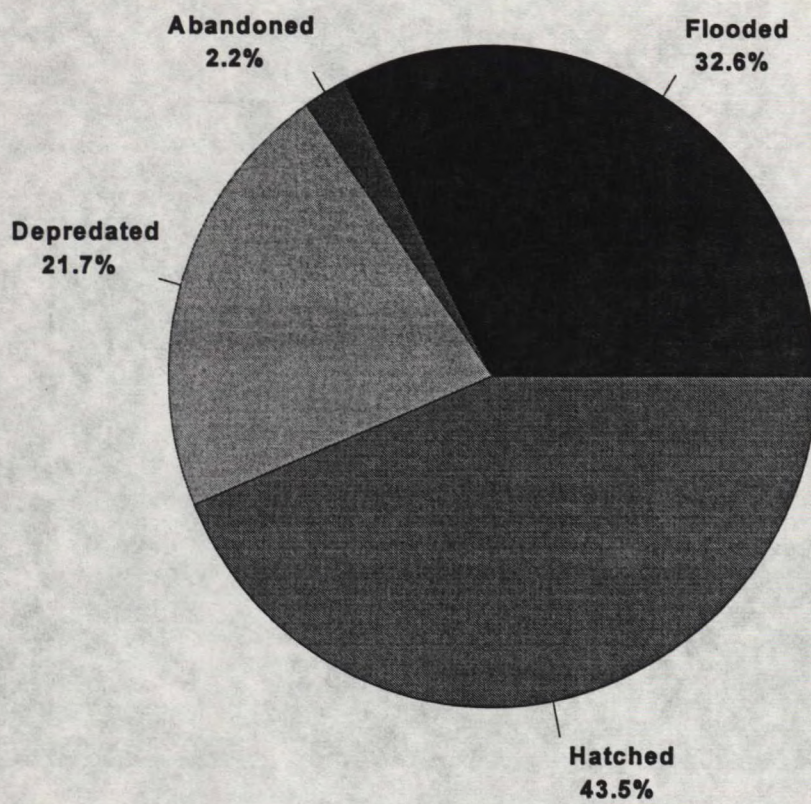


Figure 5. Fate of piping plover clutches (n = 46) at Lake Diefenbaker, Saskatchewan, 1997.

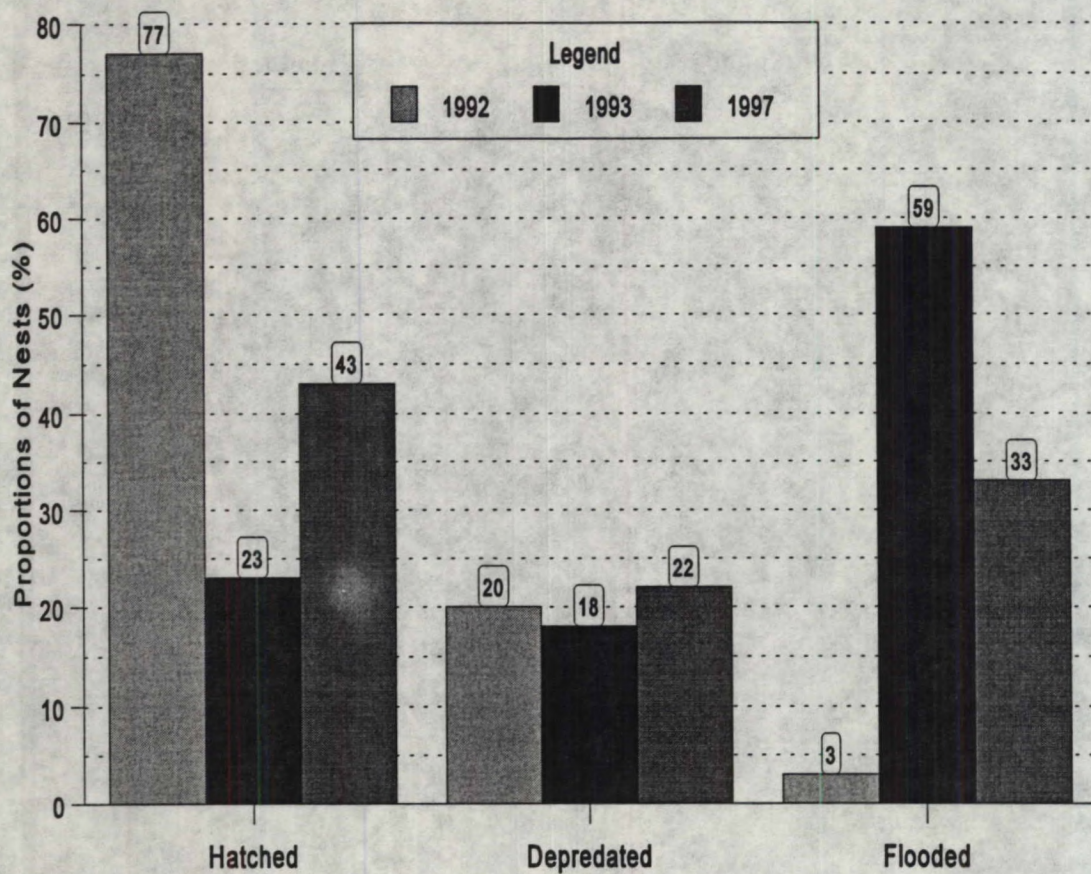


Figure 6. Fate of piping plover clutches at Lake Diefenbaker for the years 1992, 1993 and 1997. Clutch fates for 1992 and 1993 taken from Espie et al. (1996).

One nest was observed abandoned during the 1997 breeding season. Abandonment occurred immediately after an unusual snow storm on 18 May that left 3-4 cm of snow on nesting beaches, and temperatures were -1°C . Two eggs were present in the nest prior to the snow fall, and we presume that the clutch was not complete. Haig (1992) and Cairns (1982) both report that nest abandonment in piping plovers, though rare, is more likely before a full clutch is attained. As, the adults were not banded, we were unable to determine if this pair re-nested.

Flooding of nests accounted for the largest proportion of clutch failures (Figure 6). Water levels at Lake Diefenbaker rose 1.68 m between the mean clutch initiation date (12 May) and the mean hatch date (15 June), causing a dramatic decrease in the proportion of beach habitat available. Beach widths decreased on average from 30-40% during this period (Figure 7), resulting in the flooding of 15 nests (60 eggs).

Nest elevation is, most likely, a better predictor of the probability of a nest flooding than beach width. We observed a slight negative relationship between the nest site elevation and beach width at the time of nest initiation (Figure 8), however this relationship was not significant (Pearson Correlation, $p = 0.289$). The trend suggests that those nests located on the initially widest beaches, tend to also be at the lowest elevations. This is due to the flat topography of wide beaches at Lake Diefenbaker. The southwest corner of Lake Diefenbaker (referred to as Summit Creek) regularly hosts the largest concentration of nesting piping plovers at the lake (Skeel 1997, Espie 1994, Robinson and Hjertaas 1991), and is a wide, flat beach. A greater proportion of nests flooded at Summit Creek (41.67%, $n = 5$) than elsewhere at Lake Diefenbaker (29.4%, $n = 10$), which may be correlated with the observed difference in mean nest site elevations, 555.53 m ASL and 555.65 m ASL, respectively.

The proportion of nests flooded varied among years, underscoring the inter-annual variation in the impact of water levels on piping plover clutch fates at Lake Diefenbaker (Figure 6). The number of nests at each elevation, for several years, is presented in Figure 9. The Saskatchewan Water Corporation has a 1 July reservoir target level of 555.0 m ASL (A. Banga, *pers. comm.*). Unfortunately, in 1997, the lake levels rose to 1.02 m above the 1 July target level. Our data suggest that had the water level been managed to maintain the 1 July target level of 555 m ASL,

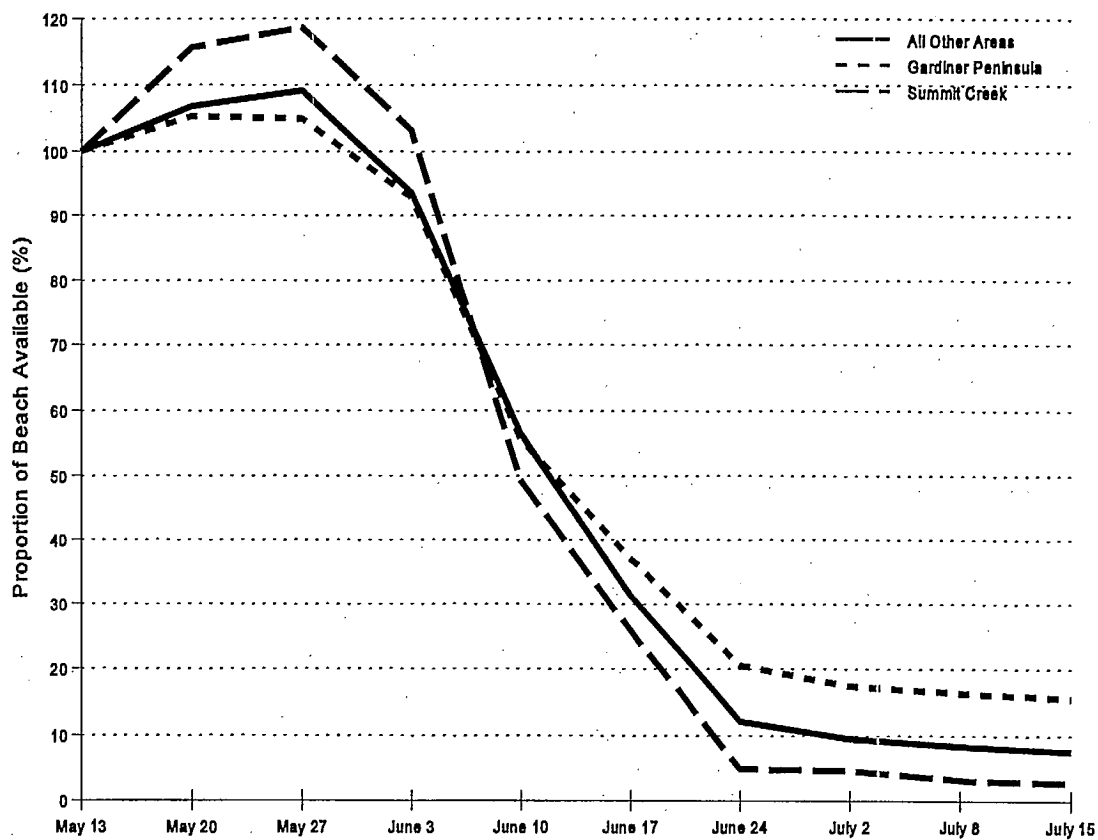


Figure 7. Temporal variation in the proportion of habitat available at piping plover nest sites ($n = 46$) over the 1997 breeding season, Lake Diefenbaker, Saskatchewan.

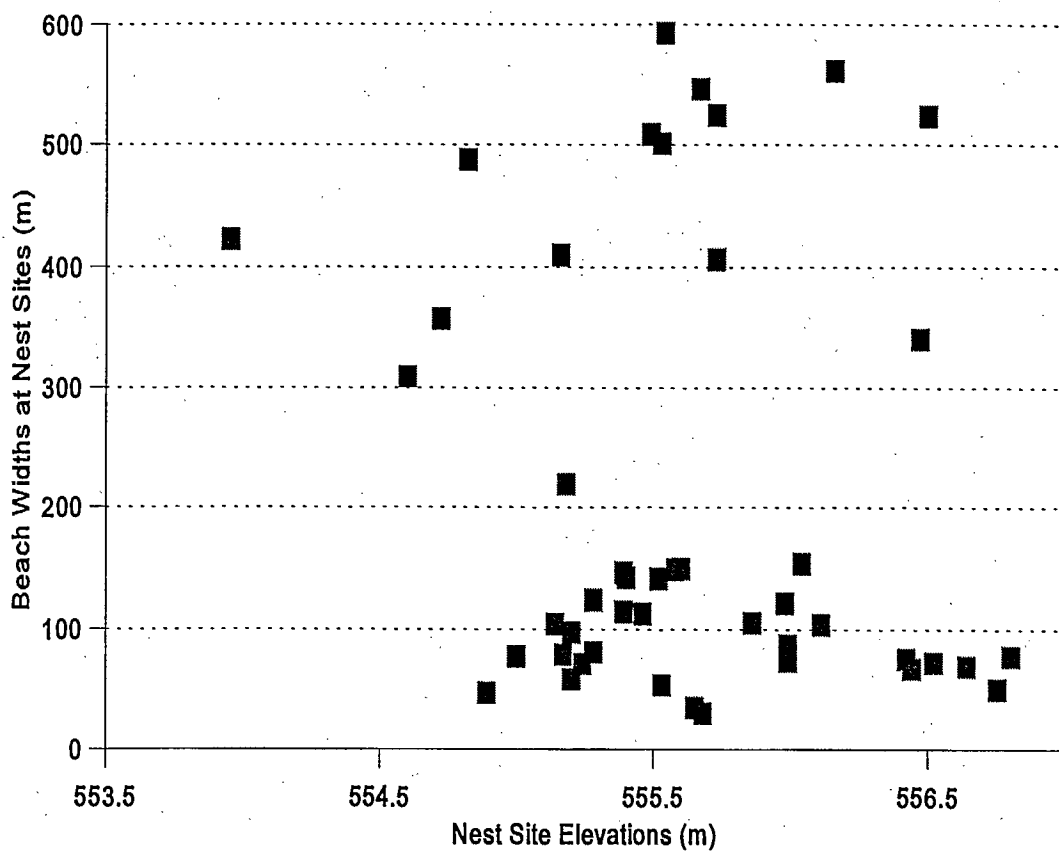


Figure 8. Relationship between nest site elevation (m ASL) and beach widths at the nest site ($n = 46$ nests) on the mean clutch initiation date (13 May) at Lake Diefenbaker in 1997.

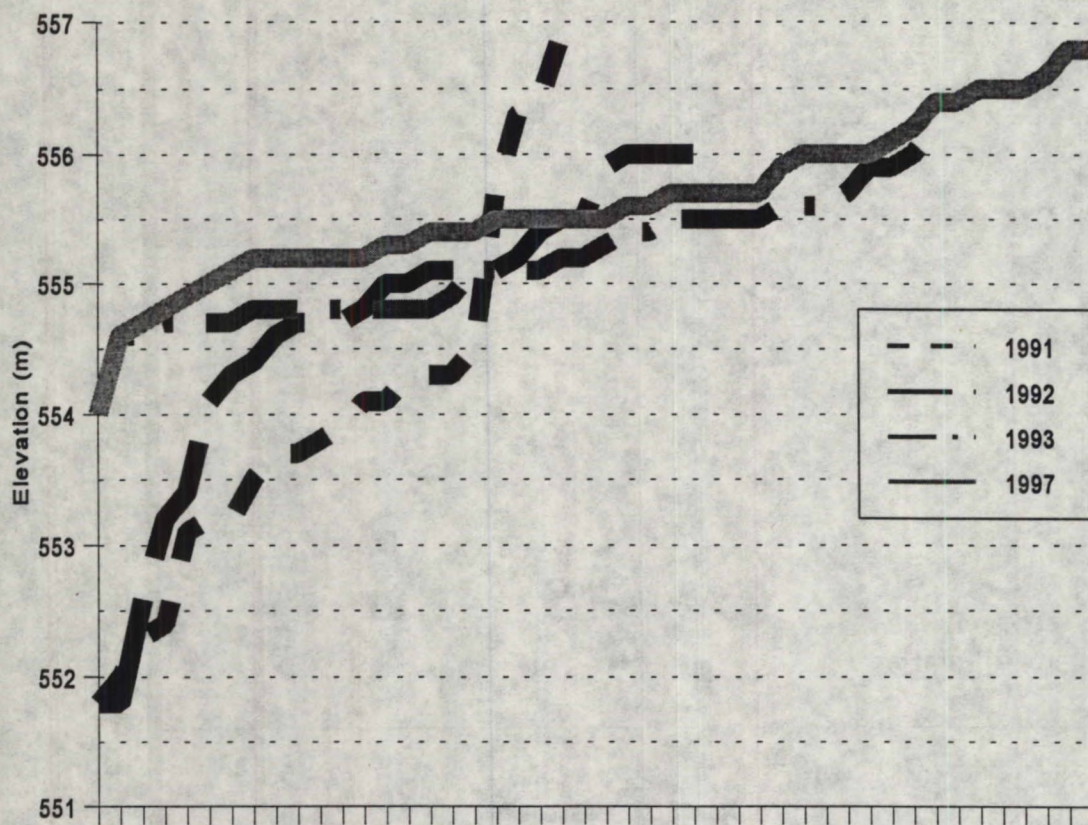


Figure 9. Variation in piping plover nest site elevations for selected years at Lake Diefenbaker, Saskatchewan. Note: data are sorted and ticks on the x axis represent an individual nest (for example, $n = 21$ nests in 1991 and $n = 46$ nests in 1997).

then only six nests would have flooded (Figure 9), as opposed to the 15 that did flood. Furthermore, approximately 40% (as opposed to 14%) of the initial nesting habitat would have remained above water.

Chick Survival

Low clutch success was further compounded by low pre-fledging chick survival rates. Twenty nests (43.5%) hatched 76 chicks, only 11 (55%) of these successfully fledged one or more chicks. Only 15 (19.7%) of the chicks produced survived to fledging. Mean brood size was 3.8 chicks/pair at hatching, but decreased to 0.75 chicks/pair by fledging. Chick mortality was greatest during the first 10 days after hatching, but continued to steadily decline until fledging (Figure 10). Brood-rearing habitat was greatly diminished at many nest sites by the mean fledging date of 15 July, with habitat availability restricted to several small remnant pockets of beach. Lake Diefenbaker water levels rose 2.75 m from the onset of the breeding season to the mean fledge date, resulting in a mean loss of 92.8% of the beach at brood-rearing areas (Figure 7). Results of our beach topography mapping show a major reduction in beach habitat availability as water levels rise (Table 2). We suggest that this loss of brood-rearing habitat contributed to high mortality of pre-fledging juveniles potentially through an increase in 1) predation, 2) inter and intra-specific competition and 3) drowning.

We speculate that large reductions in brood-rearing habitat availability may have caused high rates of predation on piping plover chicks, as the small remnant beaches would have made chicks much more conspicuous and much easier for potential predators to find, than on large beaches. As well, the presence of many individuals of other avian species that found refuge on the remnant beaches would have, most likely, competed with piping plovers for resources (e.g. space but not likely food), and attracted predators through increased activity and noise at brood-rearing areas. Unfortunately, we collected no data on predator abundance relative to beach area. We did, however, make anecdotal observations of gull (*Larus spp.*) and coyote (*Canis latrans*) activity near nest sites, which seemed to increase as beach area decreased. Additionally, irregular beach morphology resulted in beach areas becoming temporary islands before, they too eventually flooded. Some chicks were trapped on ephemeral islands and most likely drowned as rising water levels

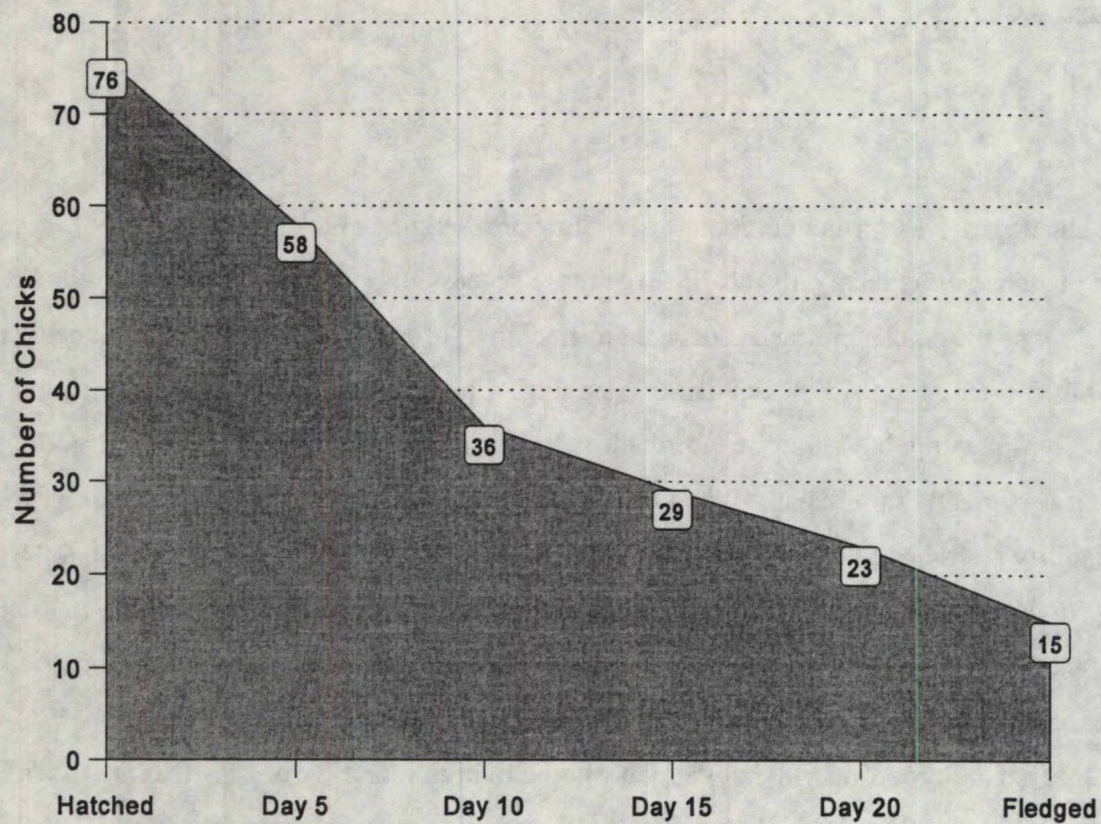


Figure 10. Number of chicks ($n = 20$ broods) surviving 5-day intervals during the brood-rearing stage at Lake Diefenbaker, Saskatchewan in 1997.

Table 2. Relationship between given water levels and beach area (m²) and width (m) at selected piping plover nesting areas at Lake Diefenbaker.

Nesting Area		551.0 m ASL	552.0 m ASL	553.0 m ASL	553.5 m ASL	554.0 m ASL	554.5 m ASL	555.0 m ASL	555.5 m ASL	556.0 m ASL
Summit Creek	Width (m)	951	782	606	n/a	361	n/a	180	n/a	68
	Area (m ²)	1235559	978689	772636	n/a	402464	n/a	169515	n/a	43805
Elbow Beach	Width (m)	n/a	n/a	n/a	60	40	30	21	14	7
	Area (m ²)	n/a	n/a	n/a	12994	9406	6913	5023	3427	1972
Douglas Prov. Park	Width (m)	n/a	n/a	n/a	100	90	72	42	0	0
	Area (m ²)	n/a	n/a	n/a	17336	15815	14258	11967	0	0
Danielson Prov. Park	Width (m)	n/a	n/a	n/a	148	112	83	60	25	0
	Area (m ²)	n/a	n/a	n/a	30282	23050	16099	11948	5364	0
Gardiner Peninsula	Width (m)	n/a	n/a	n/a	37	31	23	16	8	2
	Area (m ²)	n/a	n/a	n/a	9310	7651	5993	4687	3439	1768
Sage Bay	Width (m)	n/a	n/a	n/a	129	97	65	38	22	11
	Area (m ²)	n/a	n/a	n/a	44963	32339	23187	14222	8687	4135

engulfed these islands.

Productivity

In 1997, piping plovers breeding at Lake Diefenbaker hatched and fledged a very low number of chicks resulting in a productivity value of 0.32 chicks fledged per pair. Productivity was derived using the number of chicks that successfully fledged ($n = 15$) divided by the number of pairs observed nesting ($n = 46$).

The 1997 productivity estimate of 0.32 chicks fledged per pair is well below the 1.13 chicks fledged per pair estimated as the minimum value estimated as required for population stability in the western North American metapopulation (Ryan et al. 1993). Recently, revised modelling exercises have suggested that the population stability value of 1.13 chicks fledged per pair reported by Ryan et al. (1993) has been too conservative. A new estimate of 1.74 chicks fledged per pair has recently been advocated (J. Plissner, *pers. comm.*). Furthermore, productivity at Lake Diefenbaker in 1997 was less than the estimated average annual productivity value of 0.51 chicks fledged per pair at this site (Skeel 1997).

Survey data, preliminary modelling, and our field research, all suggest that piping plover productivity at Lake Diefenbaker is strongly limited by water supply operations (Espie et al. 1997, Skeel 1997). A significant linear regression between piping plover and the 1 July water level was observed by Skeel (1997) and confirmed ($r^2 = 0.736$, 1 df, $p = 0.001$, $n = 11$) with the 1997 data (Figure 11). Additionally, piping plover productivity was significantly ($r^2 = 0.597$, 1 df, $p = 0.005$, $n = 11$) influenced by the magnitude of change in water levels from the onset of the breeding season to the 1 July water level (Figure 12).

The question then becomes: are piping plovers breeding at Lake Diefenbaker a source, sink, or stable population? Espie et al. (*in press*) constructed a model to predict the historical piping plover productivity at Lake Diefenbaker from 1967 to 1997. Their model suggests that in a 26- year time span, piping plover productivity at Lake Diefenbaker has been above the 1.13 chicks fledged per pair estimate in only six years, and above the revised estimate of 1.74 chicks fledged per pair in

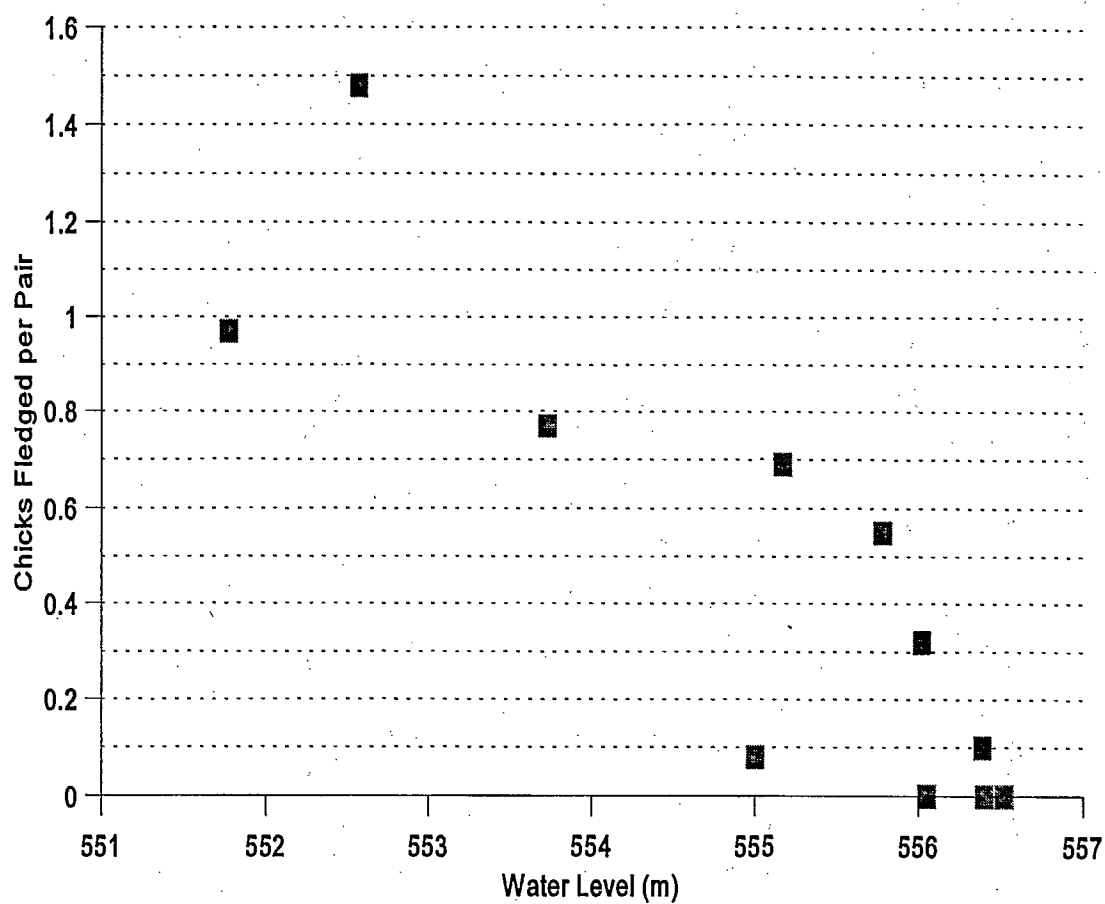


Figure 11. Relationship between piping plover productivity (chicks fledged/pair) and the 1 July water level (m ASL) for the years 1986, and 1988-1997 at Lake Diefenbaker, Saskatchewan. (Modified from Skeel 1997).

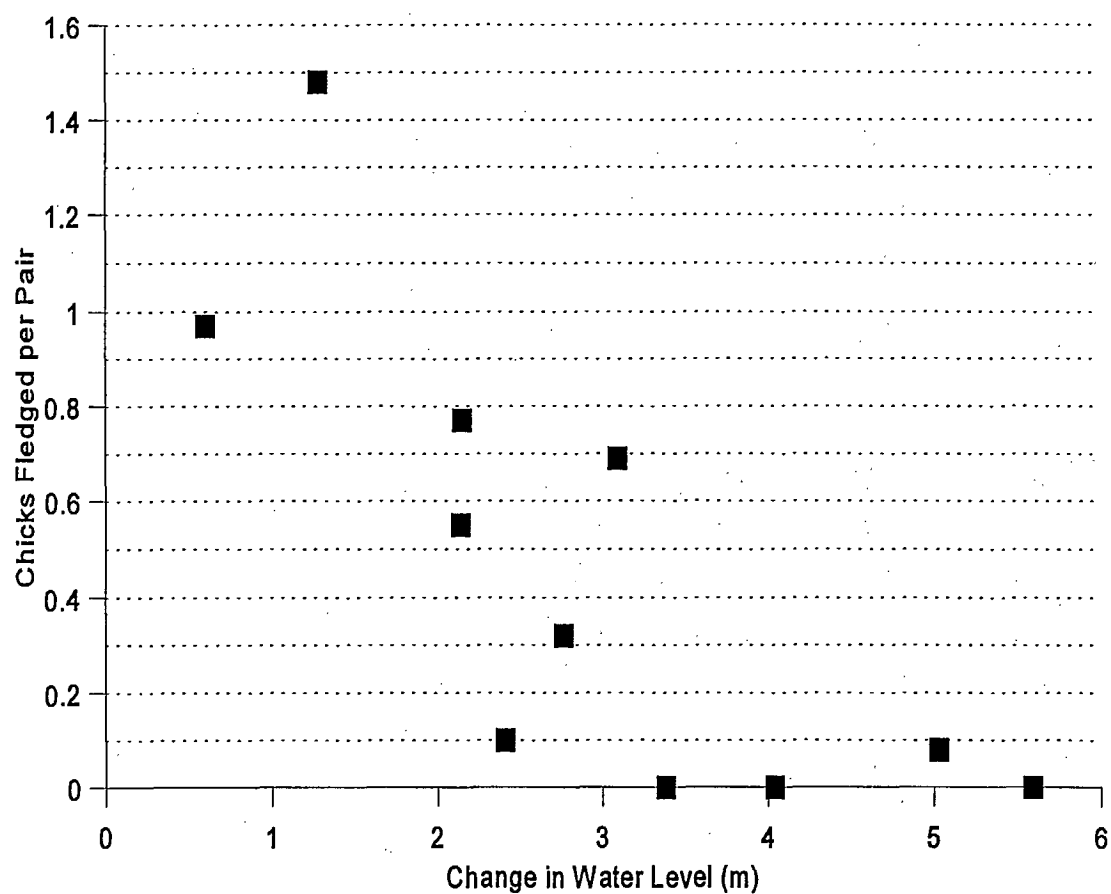


Figure 12. Relationship between piping plover productivity and the rise in water level (m) between the mean clutch initiation date (12 May) and 1 July, at Lake Diefenbaker, Saskatchewan, for the years 1986-1997. (Modified from Skeel 1997).

possibly only two years. Our findings, coupled with those of Skeel (1997) and Espie et al. (*in press*), strongly suggest that piping plovers at Lake Diefenbaker constitute a sink population. The impact of this potential sink population on metapopulation dynamics and overall species persistence in the Northern Great Plains deserves further attention.

4.3 Artificial Nest Translocations

We performed 52 clutch translocation, 50 (96.2%) of which were successful (Table 3). All seven of the pairs subjected to artificial nest translocation tolerated the procedure. No nests were abandoned, and all seven artificial nest platforms were accepted by incubating adults. With repeated translocations, we successfully moved clutches an average of 13.3 m. We moved one clutch a total distance of 30.78 m (over 14 translocations). In six instances, we moved a clutch greater than 5 m in a single day, through repeated translocations. Our maximum daily cumulative move was 10.09 m, over three successful translocations. We moved each clutch an average of 2.4 times a day (SD = 1.1, range = 1-5).

The mean time required to move a clutch was 4.1 minutes (SD = 1.2, range = 2-7 minutes). The mean distance clutches were moved was 1.90 m per translocation (SD = 0.83, range = 0.63-4.52 m). The mean time required for one of the adults to find the new clutch location was 8.8 minutes (SD = 4.53, range = 4-22 minutes).

We observed a significant amount of variability among incubating pairs in their ability to locate translocated clutches (Table 3, Figure 13, Kruskal-Wallis $p = 0.01$, $df = 6$, $n = 50$). Our data suggests that some pairs are better able to find a translocated clutch than others. These results may also be an artifact of the differences in beach substrate and morphology where the clutches were located. Piping plovers may have greater difficulty finding translocated clutches on beaches with a coarse or heterogenous substrate and/or more irregular morphology. Beaches from which clutches were translocated varied in substrate structure and morphology. Unfortunately, our small sample size prohibited analysis of habitat variables.

Table 3. Summary statistics for translocated piping plover clutches at Lake Diefenbaker, Saskatchewan, 1997.

Nest Number	Number of Times Moved	Mean Time to Move (min)	Mean Distance Moved (m)	Mean Time to Find Clutch (min)	Total Distance Moved (m)	Clutch Fate
GP-6	7	4.57 (1.4)	0.94 (0.2)	12.29 (6.3)	6.58	Destroyed
RN-1	14	4.14 (1.3)	2.20 (0.8)	7.29 (4.3)	30.78	Hatched
RN-2	9	4.11 (1.1)	1.55 (0.3)	7.78 (2.3)	13.99	Hatched
SB-3	8	4.13 (0.9)	1.63 (0.7)	13.75 (8.6)	13.07	Hatched
AC-12	2	3.00 (0)	2.35 (0.3)	10.00 (0)	4.69	Flooded
AC-7	3	3.67 (0.5)	3.36 (0.8)	8.33 (2.9)	10.09	Flooded
CB-1	9	2.63 (0.5)	1.55 (0.6)	6.00 (2.8)	13.93	Hatched

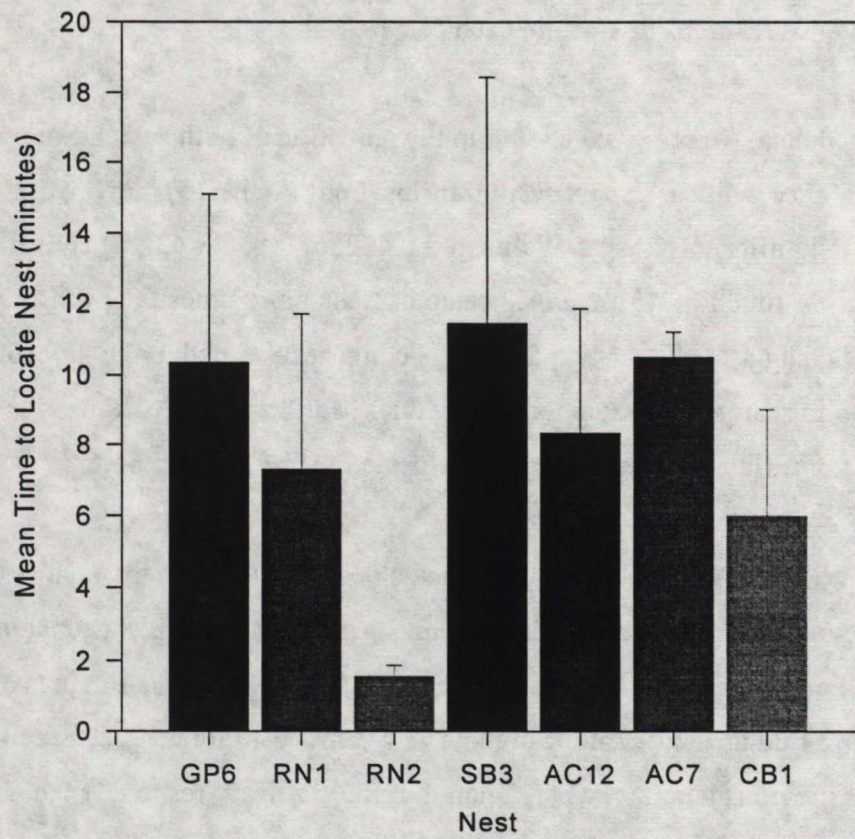


Figure 13. Variability in the mean time (± 1 SE) required by each pair to locate a translocated clutch.

With all incubating pairs pooled, there was no significant relationship between the distance a nest was moved and the time required by the breeding pair to find the new nest location (Figure 14, $r^2 = >0.001$, $y = 8.76$, $p = <0.05$, $df = 39$). Unfortunately, our sample sizes were too small to permit analysis of time-distance relationships within each pair.

With standardized data, we observed a trend in the reduction of both search time per metre moved and the variability with each subsequent translocation (Figure 15), however, this trend was not statistically significant (Kruskal-Wallis, $p = 0.459$, $df = 8$, $n = 43$). It appeared that piping plovers were taking less time to find the translocated nest the more times they were subjected to the procedure. This trend suggests that, most pairs did become accustomed to the procedure. As there is probably variation in search abilities among individuals, further investigation is warranted to determine if this factor influences the time taken to locate the translocated nest.

In most instances (96.2%) in which we performed a nest translocation the incubating adult was able to locate the new location. We observed two cases in which the adult was unable to locate the nest after translocation. In one case, we moved the nest 1.2 m and after 12 minutes of searching the pair was unable to find the new nest location. The weather deteriorated badly and we elected to return the nest to its previous location, where upon the adults quickly resumed incubation. We successfully moved this nest later the same day in favourable weather. It is possible that had we been more patient, the pair may have found the new nest location within several more minutes, but as this was one of our earlier attempts at translocating nest and the weather deteriorated we chose a more prudent action. In the second case, we moved the nest a long distance (3.53 m) through a relatively rocky beach, and over a ridge, in the rain. Any of these factors may have been responsible for the adults not finding the new nest location. As with all of our nest translocation, such a move was warranted due to the high risk of immediate flooding to the clutch. After 24 minutes of unsuccessful searching by the adults, we relocated the nest to within 0.6 m of the previous location and the adults quickly found the nest and resumed incubation. We waited 30 minutes and continued to successfully move the nest. Hjertaas (1997) also reported cases ($n = 5$) in which she attempted to move nests over small beach ridges, or over longer distances (>1.2 m), in which the adults had difficulty in locating the new nest location.

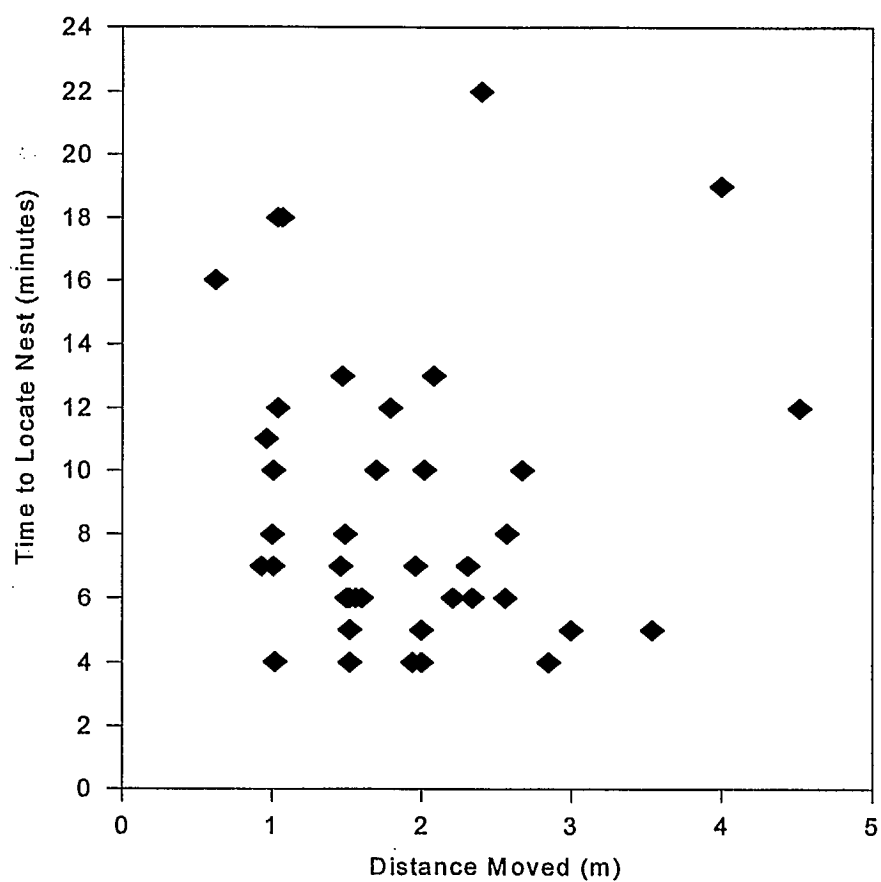


Figure 14. Relationship between the distance a clutch was translocated and the time required by the adults to find the new location (n = 51 translocations).

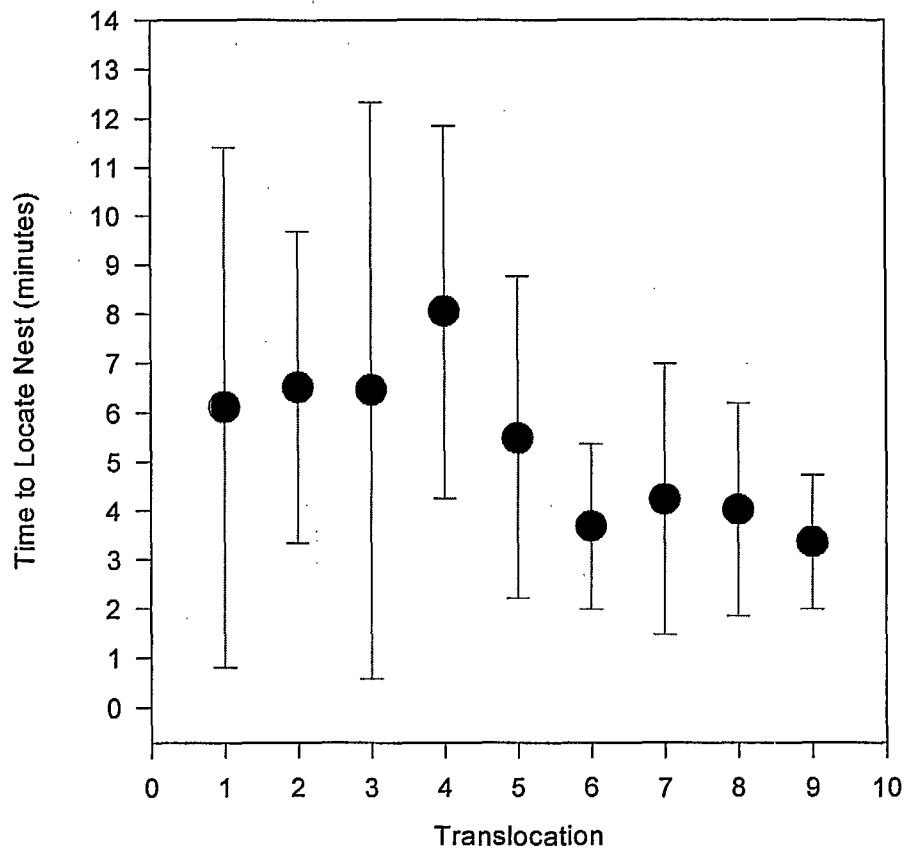


Figure 15. Relationship between the mean time required per metre by a pair to locate a new clutch location and the number of times a clutch was translocated (n = 43 moves).

Our procedure was able to prevent four of the seven clutches (57.1%) from flooding. These clutches successfully hatched 15 young. Two others flooded before they could be moved to a high enough elevation, and another was abandoned after a boat was launched within 30 cm of the artificial nest. Two of the clutches that hatched young produced three fledglings, augmenting piping plover productivity at Lake Diefenbaker.

Instances in which we were unable to prevent clutches from flooding ($n = 2$) occurred on the southwest corner of Lake Diefenbaker, where beach habitats are extremely flat and long (Table 2). Clutches on this beach would need to be moved in the order of 100 m to gain a significant increase in elevation. We were unable to move these clutches the distances required to keep pace with rising lake levels. Nests at this particular beach have a history of chronically being flooded (Robinson and Hjertaas 1991, Espie et al. 1996).

The number of clutches that can be saved from flooding is limited to those which can be moved to a safe elevation in a timely fashion. Artificial nest translocation is time and labour consuming, and requires knowledge of (1) nest site location, (2) approximate hatch date, (3) reliable forecast of water level increases, and (4) approximate date that the nest site will flood.

Artificial nest translocation can be an effective means of increasing productivity of endangered piping plovers at sites where flooding can substantially reduce nesting efforts. However, translocation is not an effective substitute for mitigation of water level management operations that jeopardize endangered species recovery. Artificial nest translocation should be undertaken as a last resort and generally, will only protect a proportion of nests. We attribute low fledging rates of translocated clutches to a dramatic reduction in brood-rearing habitat, and not to the procedure itself. Our study highlights the importance of brood-rearing habitat being available to pre-fledging juveniles. Handling of piping plover clutches carries the inherent risk of nest abandonment, egg breakage, and attracting nest predators.

4.4 Population - Hydrology Modeling

Our model predicted productivity values which were very similar to observed values for the years 1991-1993 and 1997, suggesting that the model is an accurate representation. An initial assessment of the model output (Figure 16) confirms the suggestion of the Espie et al (*in press*) model that the Lake Diefenbaker is a sink population. Our model predicted that of the 29 years taken into account (1969-1997), piping plover productivity was at a level consistent with population stability in only eight years. The model of Espie et al. (*in press*) predicted that in six of the 26 years in their model (1968-1993) piping plover productivity was above population stability. The two models varied most significantly for the years 1985 and 1989.

Both models can be criticized for the lack of crucial data on chick mortality rates, especially with respect to determination of natural chick mortality and additive chick mortality as a consequence of the loss of brood-rearing habitat. However, the strength of a modeling approach is that relationships that are difficult to assess can be explored and tested, given well thought out assumptions and sensitivity analyses (Starfield and Bleloch 1991, Starfield et al. 1995). The accuracy of both our model, and that of Espie et al. (*in press*), for those years with observed productivity data suggests that our assumptions are reasonably valid.

While our initial model is accurate, we have begun sensitivity analysis on the model parameters to increase the precision and fit of the model to observed productivity values for the years 1991-1993 and 1997. We varied the natural chick mortality rate and observed that a natural chick mortality rate of 0.45 provided a better fit of model output than did our initial value of 0.32, for three of the four years with actual observed productivity data. Furthermore, initial analysis of this parameter suggests that variation in the natural chick mortality rate, within the ranges we estimated, had a negligible effect on the accuracy of the predicted productivity values within each year (Figure 17, Pearson correlation, $p < 0.001$, $df = 3$). It appears then, that both the flooding of nests, and later in the breeding season the loss of brood-rearing habitat, may be the factors limiting piping plover productivity at this site. Additionally, examination of the natural chick mortality parameter, revealed that variations in this value do not have a impact on the productivity estimates for those years in which productivity is below population stability, but for years with higher productivity

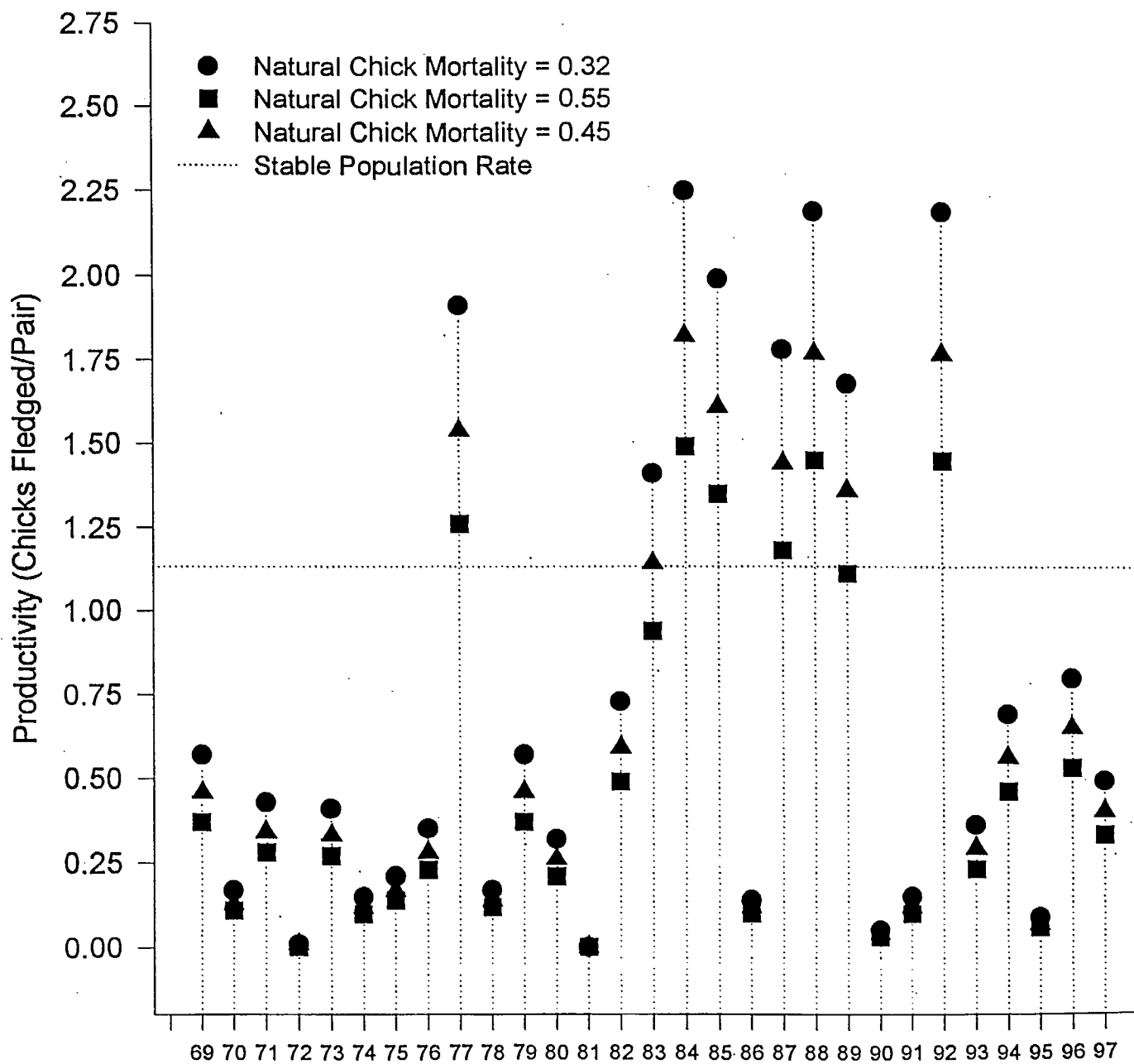


Figure 16. Model output of predicted piping plover productivity for the years 1969 to 1997 (n = 225 nests per year). Values are presented for each year using three different natural chick mortality rates.

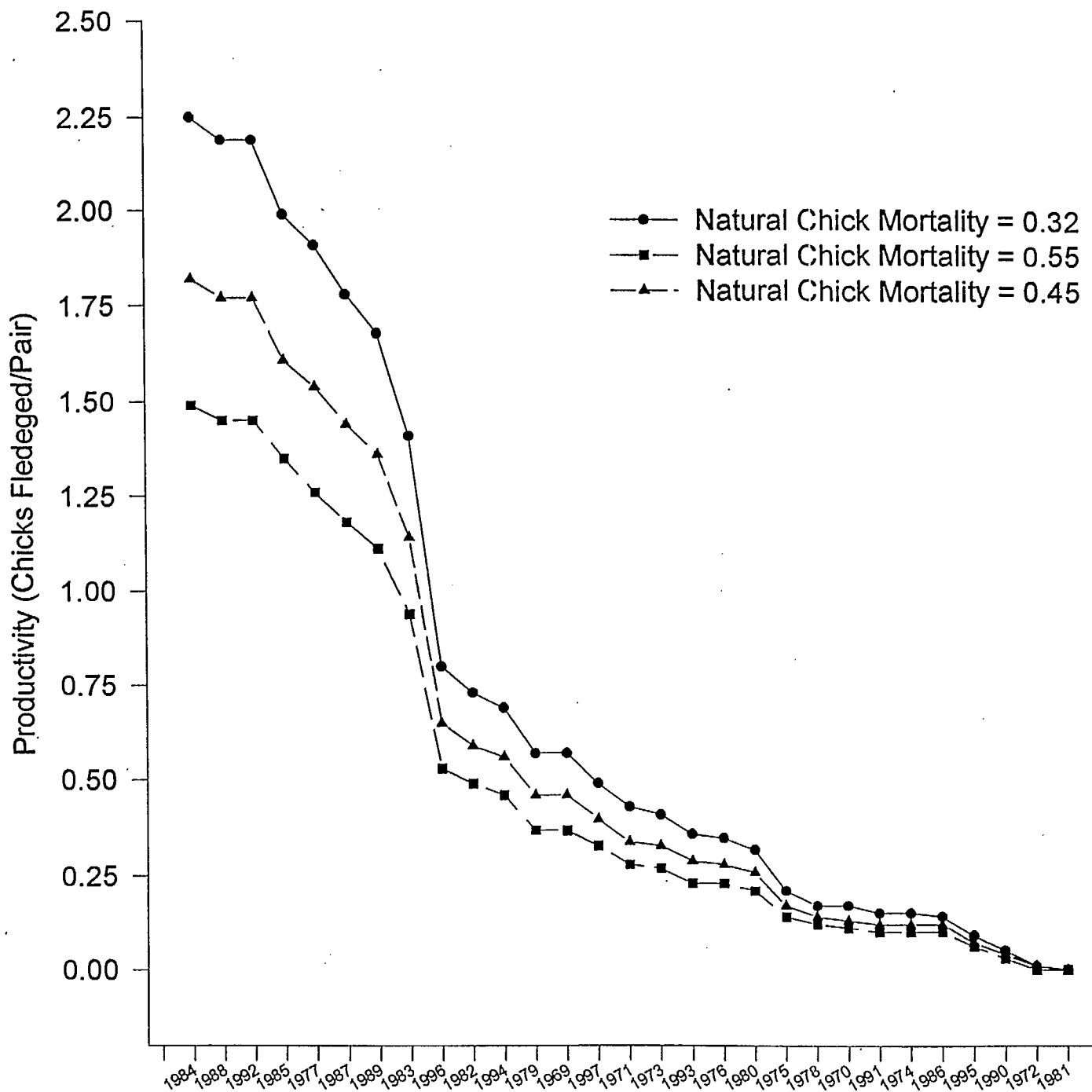


Figure 17. Sensitivity analysis of the effect of variations on the natural chick mortality rate on model output for each year 1969 to 1997 (n = 225 nests per year).

values the variation in predictions using a different input parameter fluctuates considerably (Figures 16 and 17). This suggests that our assumption of a linear relationship between the additive effect of loss of brood-rearing habitat on chick mortality rates, while accurate, may be better represented with a curvilinear relationship (probably sigmoidal in shape). We are currently exploring means of incorporating non-linear relationships into the model. Although the model appears very accurate, further sensitivity analysis will increase the precision of the model predictions.

Our model of piping plover productivity - hydrology relationships at Lake Diefenbaker, modifies and corrects some of the assumptions of the Espie et al. (*in press*) model. Precision of the model output for those years with productivity values above population stability (i.e. 1992) may be improved and tested. The basic model presented here will be used in further simulations (currently underway) aimed at evaluating the impact of adjustments in water supply operations on piping plover productivity at this important breeding site.

The model developed here, coupled with the findings of Skeel (1997) and Espie et al. (*in press*), strongly suggest that piping plovers at Lake Diefenbaker in the past and presently, constitutes a sink population. Simulation modeling of productivity enhancement strategies should be undertaken to evaluate effective alternative management actions that could be taken to ensure a viable piping plover breeding population at Lake Diefenbaker. Furthermore, the potential impact of this suspected sink population on the larger metapopulation dynamics and long-term species persistence in the Northern Great Plains deserves further attention.

5.0 Management Recommendations

Water Supply Operations

Water supply operations at Lake Diefenbaker are a significant and limiting factor on piping plover productivity. Water management regimes that maximize reservoir filling, in years with appropriate inflow levels, will hold piping plover productivity below the required population stability level of 1.13 to 1.74 chicks fledged per pair. Our data suggest that even moderate changes

in the filling regime may have a significant effect on increasing piping plover productivity. If Lake Diefenbaker was filled to no greater than 555 m ASL by the approximate fledge date of 15 July, then in some years, a significant number of nests would not flood and a much larger proportion of brood-rearing habitat would remain available to pre-fledging juveniles. Our data lead us to speculate that a 15 July lake level limit of 555 m ASL would significantly increase piping plover productivity. We have yet to model this prediction. However, increases in piping plover productivity that may result from a 555 m ASL limit to reservoir filling may not be significant enough to ensure piping plover productivity at a population stability level. The impact of various water management scenarios needs to be explored. Further data collection, coupled with our simulation modeling, will provide further insight into these important questions. Nonetheless, our findings, coupled with those of Espie et al. (1996, *in press*) and Skeel (1997), clearly demonstrate that water supply operations at Lake Diefenbaker are the most important limiting factor for endangered piping plovers at this site. Accordingly, our strongest management recommendation is to pursue reservoir filling regimes that are more sensitive to the breeding habitat requirements of piping plovers.

Artificial Nest Translocations

Ideally, water level management operations should be pursued that minimize the risk of flooding endangered species nests. We recognize that operational modifications must take in socio-economic concerns but should also accommodate endangered species concerns when possible. Even under more favourable water management operations, the fact that some nests will flood at these sites, is inescapable. Our pilot study of nest translocations showed that this remedial action may be effective in increasing productivity, if close monitoring of known nest is carried out, and a reasonable amount of brood-rearing habitat is provided until the end of the fledging period (i.e. 31 July). The Gardiner Dam, Sage Bay, and Hitchcock Bay nesting areas (Figure 3) provide the best potential for this procedure, because the morphology of these beaches is such that distances that most nests would need to be moved would be sufficient to place clutches at a higher and therefore safer elevation. However, without water management accommodation of piping plover brood-rearing habitat, nest translocations may be unproductive.

Nest Exclosures

Nest predation is one of the most significant factors limiting piping plover productivity in the Northern Great Plains (Espie et al. 1996, Smith et al. 1993, Prindiville Gaines and Ryan 1988, Whyte 1985). At Lake Diefenbaker, data from three years of closely monitored nests show that approximately 20% of the nests are depredated each year. Clearly, achieving a decrease in nest predation rates should be a management priority. At many other piping plover breeding sites, nest exclosures and/or fencing have been used to decrease nest predation, and hence increase productivity (Smith et al. 1993, Mayer and Ryan 1991, Rimmer and Deblinger 1990). While nest exclosures can cause some problems with individual nests (Deblinger et al. 1992), they are an effective means for increasing productivity and should be considered as part of a piping plover management strategy at Lake Diefenbaker. The low densities of piping plover nests at specific beaches, coupled with the size and dynamic nature of the beaches at Lake Diefenbaker, make electric fencing an impractical option. Rather, a separate exclosure for each known nest could be used at Lake Diefenbaker. Nest exclosures, too, will have limited benefits in augmenting piping plover productivity if water management practices at Lake Diefenbaker limit the amount of suitable habitat during the brood-rearing period.

Human Use of Nesting Beaches

The impact of cattle and human recreational use of piping plover nesting beaches at Lake Diefenbaker is not fully understood. Research in eastern North America, however, strongly suggests that human disturbances to nesting piping plovers has a significant negative impact on productivity (Loefering and Fraser 1995, Melvin et al. 1994, Patterson et al. 1991, Flemming et al. 1988). Several important piping plover breeding areas at Lake Diefenbaker are used by humans for recreational purposes (i.e. Gardiner Dam, Summit Creek and Hitchcock Bay). At these sites, evidence of vehicles was observed in close proximity to nests. No nests were observed crushed by vehicles, but several tire tracks were seen very close to piping plover nests. Additionally, stress imposed on adult and pre-fledging juveniles by close proximity of humans and their vehicles may have a deleterious impact on their fitness and survival (Melvin et al. 1994, Patterson et al. 1991, Flemming et al. 1988). In 1997, we were provided with signs by Danielson Provincial Park, that

denoted the presence of endangered piping plover nesting activities and requesting human visitors to limit their movements in a given area. We erected three signs at the Gardiner Dam site. Two of the signs were vandalized and the use of vehicles on the beaches continued.

We recommend that greater efforts be made to limit vehicle use at endangered species nesting areas at Lake Diefenbaker during the breeding season (6 May to 31 July). The Gardiner Dam and Summit Creek beaches are within the boundaries of provincial parks and as such, vehicle use of these beaches should be prohibited. An increase in public education at the provincial parks, through their interpretative programs, may aid in awareness of the piping plover's plight and its requirements at Lake Diefenbaker. We strongly recommend a combination of increased public education and greater law enforcement, with respect to human recreational use of piping plover nesting beaches at provincial parks located by Lake Diefenbaker.

6.0 Acknowledgements

We thank P. Trefry (Canadian Wildlife Service), M. Skeel (Nature Saskatchewan), Ron Bazuk (Saskatchewan Water Corporation) and census volunteers (M. Worel and D. Vetter) for field assistance. The Saskatchewan Water Corporation provided 1997 Lake Diefenbaker water level data. We thank Douglas Provincial Park and Danielson Provincial Park for boat services and logistical assistance. Dr. Trent Bollinger (Canadian Cooperative Wildlife Health Centre, Saskatoon) performed the necropsy of egg contents. We also thank S. Barry (Canadian Wildlife Service), M. Skeel (Nature Saskatchewan) and E. Wiltse (Saskatchewan Environment and Resource Management) for reviewing an earlier draft(s) of this report. Funding for this project was provided by Environment Canada, Human Resources Development Canada, Enbridge Inc. (formerly Interprovincial Pipe Line Incorporated), National Fish and Wildlife Foundation, Nature Saskatchewan and World Wildlife Fund (Canada).

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APPENDICES

Appendix 1. Gross necropsy results for salvaged piping plover eggs from Lake Diefenbaker (1997).

Seventeen Piping Plovers eggs were collected (Table 1) from nests which failed to hatch all eggs or were flooded out at Lake Diefenbaker, Saskatchewan during 1997. After collection, eggs were wrapped in foil and placed in a freezer compartment for temporary storage. On 23 July 1997, all eggs were submitted to the Canadian Cooperative Wildlife Health Centre in Saskatoon for necropsy. Eggs were then kept frozen at -20°C until 24 March 1998 when Dr. Trent Bollinger carried out the necropsies. Some embryos or portions of embryos were taken for histological and DNA analyses.

Eleven of the 17 eggs (64.7%) contained embryos, however, none showed any visible abnormalities. The average egg length (mm) and width (mm) of fifteen eggs measured was $305 \pm 27.1(\text{SD})$ and $250.9 \pm 24.4 (\text{SD})$, respectively. Egg weight averaged $8.4 \pm 0.3 \text{ g}$. Mean embryo length ($n = 9$) was $315.7 \pm 19.1(\text{SD}) \text{ mm}$ and mean embryo weight $1.6 \pm 0.4 (\text{SD}) \text{ g}$.

Table 1. Necropsy results for Piping Plover eggs from failed or flooded nests in 1997 at Lake Diefenbaker, Saskatchewan. (Data from Dr. Trent Bollinger, Canadian Cooperative Wildlife Health Centre, Saskatoon).

Nest No.	Collection Date	Egg	Egg Length (mm)	Egg Width (mm)	Egg Weight (g)	Embryo Length ¹ (mm)	Embryo Weight (g)
RN97-1* ²	25 June	A ³	306	241	8.2	N/E ⁴	N/E
RN97-3*	24 June	A	-	-	-	N/E	N/E
RN97-3*	24 June	B	313	236	8.0	N/E	N/E
RN97-3*	24 June	C	295	244	8.3	N/E	N/E
AC97-19	23 July	A	249	309	8.6	350	2.1
AC97-19	23 July	B	243	312	8.4	323	1.8
AC97-19	23 July	C	306	243	8.5	325	1.9
AC97-16	23 July	A	316	239	8.3	330	1.8
AC97-16	23 July	B	306	241	8.1	320	1.6
DN97-9	25 June	A	342	245	8.7	N/E	N/E
DN97-9	25 June	B	342	246	9.0	N/E	N/E
GP97-6*	18 June	A	314	244	8.6	295	1.3
GP97-6*	18 June	B	315	244	8.4	309	1.5
DN97-3*	18 June	A	305	236	7.9	293	1.2
DN97-3*	18 June	B	310	243	8.0	296	0.9
DN97-3*	18 June	C	315	241	8.7	E ⁵	E
DN97-3*	18 June	D	-	-	-	E	E
$\bar{x} \pm SD$	-	-	305.1 \pm 27.1	250.9 \pm 24.4	8.4 \pm 0.3	315.7 \pm 19.1	1.6 \pm 0.4
N=	-	17	15	15	15	9	9

¹ Embryo length measured from crown to rump.

² * = Nest flooded by rising waters.

³ Does not connote laying order.

⁴ N/E = no embryo.

⁵ E= Embryo present but no length or weight data.

Appendix 2. Summary data for monitored nests at Lake Diefenbaker in 1997.

Nest Number	Clutch Fate	No. Eggs Laid	Dating Method *	Clutch Initiation Date	No. Eggs Hatched	Hatch Date	No. Chicks Fledged	Fledge Date	Nest Elevation
AC97-1	Depredated	4	B	May 7	0	June 9	0	July 3	555.73
AC97-2	Depredated	4	B	May 9	0	June 11	0	July 5	555.54
AC97-3	Depredated	4	B	May 11	0	June 13	0	July 7	555.73
AC97-4	Hatched	4	A	May 13	4	June 15	1	July 9	556.47
AC97-5	Flooded	4	B	May 21	0	June 23	0	July 17	554.72
AC97-6	Depredated	4	C	May 22	0	June 24	0	July 18	556.16
AC97-7	Flooded	4	B	May 25	0	June 27	0	July 22	555.49
AC97-8	Hatched	4	A	May 17	3	June 19	0	July 13	555.53
AC97-9	Depredated	4	B	May 23	0	June 25	0	July 19	556.50
AC97-10	Flooded	4	B	May 28	0	June 30	0	July 24	553.95
AC97-11	Flooded	4	B	May 27	0	June 29	0	July 23	554.82
AC97-12	Flooded	4	B	May 30	0	July 2	0	July 27	555.67
SB97-1	Hatched	4	A	May 8	4	June 8	0	July 4	555.39
SB97-2	Depredated	4	B	May 17	0	June 18	0	July 12	555.52
SB97-3	Flooded	4	A	May 20	0	June 22	0	July 16	556.04
GP97-1	Hatched	4	A	May 6	4	June 9	1	July 3	556.80
GP97-2	Hatched	4	A	May 16	4	June 19	0	July 13	556.75
GP97-3	Hatched	4	A	May 12	4	June 14	0	July 8	555.24
GP97-4	Hatched	4	A	May 12	4	June 14	0	July 8	556.42
GP97-5	Hatched	4	A	May 15	4	June 18	0	July 13	555.39
GP97-6	Flooded	4	C	May 26	0	June 28	0	July 22	554.89
GP97-7	Hatched	4	A	May 11	4	June 13	1	July 7	556.64
DN97-1	Abandoned	2	C	May 15	0	June 16	0	July 10	555.58
DN97-2	Depredated	4	B	May 12	0	June 15	0	July 8	555.60
DN97-3	Flooded	4	B	May 31	0	July 2	0	July 27	555.18
DN97-4	Hatched	4	A	May 10	4	June 13	2	July 7	555.28
DN97-5	Hatched	4	A	May 12	4	June 15	2	July 9	555.99
DN97-6	Depredated	4	C	May 28	0	June 30	0	July 23	555.28
DN97-7	Hatched	4	A	May 11	4	June 13	0	July 7	555.65
DN97-8	Hatched	4	A	May 15	4	June 17	0	July 11	555.68
DN97-9	Hatched	4	A	May 15	2	June 14	1	July 8	556.52
DN97-10	Flooded	3	C	June 4	0	July 8	0	August 1	556.11
RN97-1	Flooded	4	A	May 24	0	June 23	0	July 17	555.00
RN97-2	Flooded	4	A	May 23	0	June 22	0	July 16	555.14
RN97-3	Hatched	4	A	May 15	4	June 15	0	July 9	555.40
RN97-4	Flooded	4	C	May 15	0	June 14	0	July 8	555.46

Nest Number	Clutch Fate	No. Eggs Laid	Dating Method *	Clutch Initiation Date	No. Eggs Hatched	Hatch Date	No. Chicks Fledged	Fledge Date	Nest Elevation
RN97-5	Hatched	4	A	May 12	4	June 11	4	July 6	555.99
DG97-1	Depredated	4	C	May 20	0	June 19	0	July 13	555.53
DG97-2	Depredated	4	C	May 16	0	June 18	0	July 12	555.20
RS97-1	Hatched	4	A	May 11	4	June 13	0	July 7	555.20
CB97-1	Flooded	4	A	May 20	0	June 22	0	July 16	555.17
CB97-2	Hatched	4	A	May 12	4	June 13	1	July 8	555.98
CB97-3	Hatched	4	A	May 13	3	June 12	0	July 6	556.44
MA97-1	Hatched	4	A	May 14	4	June 13	2	July 7	555.86
MA97-2	Flooded	4	C	May 27	0	June 26	0	July 20	555.16
MA97-3	Flooded	4	C	May 26	0	June 25	0	July 19	554.60
RENESTS **									
AC97-13	Depredated	1	D	ca. June 25	0	July 18-22	0		556.25
AC97-14	Depredated	3	D	ca. June 25	0	July 18-22	0		n/a
AC97-15	Depredated	3	D	ca. June 21	0	July 16-20	0		556.30
AC97-16	Abandoned	2	C	June 27	0	July 18	0		556.27
AC97-17	Trampled?	4	B	July 2	0	August 2	0		556.45
AC97-18	Depredated	1	D	before July 8	0		0		556.29
AC97-19	Abandoned	3	D	ca. June 21	0	July 16-20	0		556.29

* Hatching and fledging dates determined by one of the following four methods: A = observed hatch dates, B = egg laying sequence, C = egg flotation and D = estimates.

** Renests were not used in primary analysis of clutch fate or productivity.

Appendix 3. Piping plover population surveys at Chaplin Lake
(part of the Chaplin/Old Wives/Reed lakes Western
Hemisphere Shorebird Reserve), Saskatchewan: 1997 report

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Introduction

The piping plover (*Charadrius melodus*) is a small, migratory shorebird that has undergone a considerable population decline since European settlement. As such, the piping plover has been listed as endangered in Canada and the American Great Lakes, and threatened elsewhere in the United States (Haig 1992). Population recovery for this species largely depends on accurate population assessments of breeding populations, through continuous monitoring.

In both the 1991 and 1996 international piping plover censuses, Chaplin Lake ranked among the largest piping plover breeding populations in the Canadian prairies (Haig and Plissner 1992, Skeel et al. 1997). Factors that make this site an attractive breeding site to piping plovers are unclear. Plausible reasons may be both the quantity and quality of habitat and prey abundance. Population monitoring has been undertaken at Chaplin Lake intermittently since 1984. These surveys suggest that populations at this site are typical of other Great Plains sites, in that they exhibit wide variations in size between years. The usual explanation for such wide annual fluctuations in population sizes is the variable amount of available habitat.

Perhaps more important than the size of the population at Chaplin Lake, limited brood survey data suggest that productivity at this site may be above that recommended for population recovery (Skeel et al. 1997, Harris and Lamont 1990). Ryan et al. (1993), through simulation modelling, constructed a population viability analysis of piping plover demographics in the Great Plains. Their model estimated that for population stability, productivity would need to be at a minimum value of 1.13 chicks fledged per pair. However, in most years, few populations in the Great Plains fledge young at this rate (Prindiville Gaines et al. 1988, Espie et al. 1996, Jung et al. 1998). Estimated productivity values for Chaplin Lake range from 1.61 to 1.97. In some years, the Chaplin Lake population may act as an important source population within the larger piping plover metapopulation.

Two piping plover surveys were carried out at Chaplin Lake during the 1997 breeding season. Our objectives were to 1) estimate the piping plover population size, 2) identify portions of the lake used by piping plovers, and 3) estimate piping plover productivity.

Study Area

Chaplin Lake (50°24'N, 107°37'W) is a large saline lake, located in southern Saskatchewan. Input flows to and within the lake, are regulated and the lake is divided into three main basins and one bay (Figure 1). The western basin is further divided into cells, each with varying water levels. The division and regulation of the lake is to facilitate a large salt extraction plant located at the northern end of the lake. Water levels at Chaplin Lake vary annually due in part to precipitation cycles, and in part, to water regulation among the basins. There is approximately 106 km of shoreline at Chaplin Lake, providing a variable amount of beach habitat to shorebirds. Land use adjacent to the lake is almost entirely pasture.

In May 1997, Chaplin Lake, combined with Old Wives and Reed lakes, was designated as the fifth Canadian shorebird reserve in the Western Hemisphere Shorebird Reserve Network (G. Beyersbergen, pers. comm.). The Hemispheric Site designation of these lakes was due to the abundance and diversity of shorebirds continually observed at this site, including a relatively large breeding population of the endangered piping plover.

Methods

Despite cryptic colouration, the behaviour and habitat used by piping plovers make it a conspicuous bird, readily censused by direct counting in suitable breeding areas. Two separate censuses were carried out: 1) a breeding pair survey from 30 May - 1 June (B. Aitken, I.A. Bisson, T. Jung and B. Neufeld), and 2) a brood survey on 9 July (B. Aitken, I.A. Bisson, J.P. Goossen, and T. Jung). Survey methods were basically as in the piping plover survey protocol of Goossen (1990).

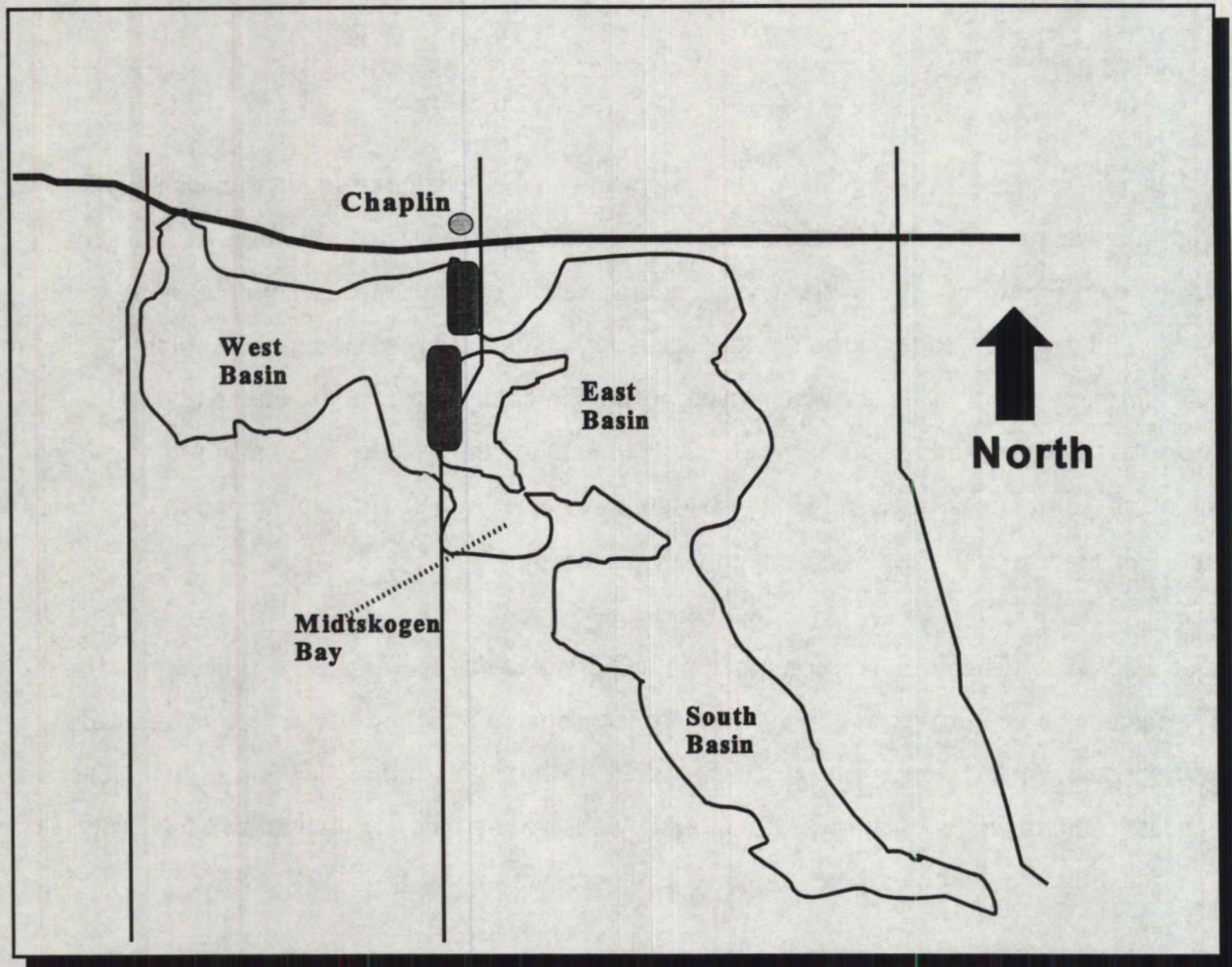


Figure 1. Stylized map of Chaplin Lake, Saskatchewan (not to scale). Shaded areas represent those beaches surveyed during the July 1997 brood census.

The entire lake was searched for adult piping plovers during the breeding pair survey. The western basin had wide beaches (<200 m wide) that were best searched by two to four observers walking 100-150 m apart, parallel to the water's edge. Midstokgen Bay, and both the eastern and southern basins, contained little suitable habitat (>50 m wide), and were thus censused using All Terrain Vehicles to traverse the shoreline. Once a piping plover was located, we observed the individual for a maximum of five minutes to ascertain its breeding status, while minimizing disturbance. Where a pair was suspected, we made an effort to locate both birds. We did not, however, attempt to locate any nests. Breeding status was assigned by observation of behavioural cues (Cairns 1982), using the following classifications: 1) pair, 2) territorial single, 3) non-territorial single, and 4) undetermined single. We mapped the approximate location of the bird, the number of birds, and their status on 1:50,000 topographic maps (map sheet 72 J/7). We used the number of pairs observed, plus the number of territorial singles seen, to estimate the number of breeding pairs present at Chaplin Lake.

During the breeding pair survey, we recorded the approximate quantity of available beach habitat in each portion of the lake. Where beach habitat occurred, we also noted the relative quality of habitat (i.e. amount of vegetation encroachment).

On 9 July, we carried out a brood survey. We censused two separate and disjunct beaches (4.8 and 1.9 km in length) located on the western basin (Figure 1), for piping plover chicks. Surveys were conducted by four people walking 100 m apart and parallel to the shoreline. Spotting scopes and binoculars were used to locate as many chicks as possible. We estimated the age-class of each chick observed and recorded the number in each apparent family group. To assign a value of the number of young per pair, we divided the total number of chicks observed by the number of suspected pairs observed in the same area during the June breeding pair survey.

Results and Discussion

Breeding Pair Survey

A total of 130 adult piping plovers was observed during the June census. The number of observed pairs was 40 (Table 1).

Table 1. Summary of adult piping plovers observed at Chaplin Lake, Saskatchewan during the breeding pair census (30 May - 1 June 1997).

Basin	Pairs	Territorial Singles	Non-territorial Singles	Undetermined Singles
West Basin	33	10	10	14
Midtskogen Bay	1	1	2	0
East Basin	5	4	3	1
South Basin	1	2	2	1
Totals	40	17	17	16

A large proportion (76.92%, $n = 100$) of birds observed were found in the western basin, which coincidentally was the smallest basin (Table 2). The western basin has had disproportionately large concentrations of piping plovers in most other years (Harris and Lamont 1990). Few birds ($n = 30$) were seen on other larger portions of the lake (Table 2). Most notably Midtskogen Bay, which has previously hosted a large number of birds in other years, had little habitat and few piping plovers in 1997. The number of adults observed at Chaplin Lake in 1997 was considerably lower than those observed in 1996 (Table 3). The limited census data suggest that piping plover population sizes at Chaplin Lake may be cyclical. Population sizes at Chaplin Lake most likely follow the local drought-flood precipitation cycle, which creates a variable amount of beach habitat available to shorebirds between years.

Brood Survey

We observed a total of 24 chicks at both beaches searched during the brood survey. Observed chicks varied in approximate age from young downies (ie. 2-5 days old) to near fledging (i.e. 24-27 days old). We based our age determinations on relative chick size, mobility, and appearance, compared to closely monitored chicks of a known age at another study site (Lake Diefenbaker, Saskatchewan). Based on the estimated number of pairs along these beaches ($n = 14$), we estimate a value of 1.71 chicks per pair, present during the July brood survey. Our estimate of young is similar to the values obtained in 1990 and 1991, 1.97 and 1.61 respectively (Harris and Lamont 1990, Haig and Plissner 1992), which were obtained in a similar fashion. These values are above the population stability figure of 1.13 chicks fledged per pair, provided

Table 2. Number of piping plovers observed at Chaplin Lake (30 May - 1 June 1997).

Basin	Shoreline (km)	Proportion of Lake	Piping Plovers Observed	Proportion of Piping Plovers
West Basin	19	0.179	100	76.9%
Midtskogen Bay	5	0.047	5	3.8%
East Basin	34	0.321	18	13.9%
South Basin	48	0.453	7	5.4%
Totals	106	1	130	100%

Table 3. Population counts of piping plovers at Chaplin Lake, Saskatchewan. Data prior to 1997 obtained from Harris and Lamont (1990) and Skeel (1997).

Year	Number of Adult Piping Plovers	Number of Young Piping Plovers	Estimated Number of Young per Pair
1984	253	-	-
1987	57	23	-
1988	17	3	-
1990	66	59	1.97
1991	113	82	1.61
1996	205	-	-
1997	130	24	1.71*

* Rate based on 14 pairs and 24 young (see text).

by Ryan et al. (1993). However, the questions remain as to: 1) how accurate are these productivity estimates for the entire lake, 2) from exactly how many pairs were these chicks produced, and 3) how accurate are these estimates with respect to actual fledging rates?

Our data do not allow for an assessment of these questions. Although, we can suggest with a fair amount of confidence that our estimate of productivity would be greater, to an unknown extent, than the actual number of chicks fledged per pair. The results of specific chick survival studies, unanimously show a marked decrease in the probability of survival during the pre-fledging stage, particularly between the ages of one to ten days old, but up to and including 27 days old (Jung et al. 1998, Loegering and Fraser 1995, Patterson et al. 1991, Prindiville Gaines and Ryan 1988). During our brood survey, we observed chicks of all age-classes, and it is highly probable that an unknown number did not survive to fledging.

Habitat Availability

The large portion of birds observed in the relatively small eastern basin is almost certainly due to the spatial variability of beach habitat availability at Chaplin Lake. All of the shoreline around the western basin contained beach habitat. However, vegetation encroachment on these saline beaches was apparent in both surveys, suggesting that these beaches had not been inundated for one or more years. A lack of flooding of these beaches may result in further vegetation encroachment in ensuing years, reducing the availability of shorebird habitat.

We estimate that less than 5% of the eastern and southern basins and Midstokgen Bay, contained suitable piping plover nesting or foraging habitat. Water levels in these basins were very high and most of the beach areas were inundated well beyond the previous year's vegetation line. Where remnant beaches did exist we often observed solitary, or in some cases, pairs of piping plovers. The flooding of beaches in these basins, while detrimental for piping plovers in 1997, will most likely create suitable beach habitat in future years.

Conclusions and Recommendations

Despite a considerable amount of piping plover habitat being underwater, Chaplin Lake continues to be an important breeding site for piping plovers in the Canadian Prairies. The number of birds at Chaplin Lake in 1997 was greater than at Lake Diefenbaker ($n = 117$, Jung et al. 1998), but less than at Big Quill Lake ($n = 427$, Prairie Environmental Services 1998).

Beyond the number of birds reported here during the breeding season, the number of young produced at this site suggest that productivity here may exceed the number required for population stability. As such, Chaplin Lake may serve a significant role as a source population. Unfortunately, available data to support this claim are inadequate. A detailed examination of

pipng plover productivity needs to be undertaken at this important breeding site. Factors limiting productivity should be investigated, and where feasible, remedial actions to enhance productivity should be carried out.

Chaplin Lake has the potential to become a premier bird-watching destination. The recent inclusion of this site within the Western Hemisphere Shorebird Reserve Network, coupled with its accessible location and remarkable diversity and abundance of grassland wildlife, will be a significant draw for the ecotourism industry. Infrastructure to support recreational bird-watching is at present minimal, however, plans are in place to increase accessibility to wildlife habitats at this site. In light of the issue of human disturbance impacts on piping plovers on the Atlantic coast, we recommend that piping plover viewing opportunities at Chaplin Lake be limited to specific sites where visitor activities can be controlled. Conversely, ecotourism at Chaplin Lake can provide an excellent mechanism for the dissemination of public education about the piping plover and other wildlife.

Acknowledgements

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