HARLEQUIN DUCK USE OF THE McLEOD RIVER WATERSHED

1998 Progress Report for the Cheviot Harlequin Duck Study

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Executive Summary

To address unknowns identified in the environmental assessment prepared for the proposed Cheviot Mine, Cardinal River Coals Ltd. initiated a detailed Harlequin Duck study in May 1996 which was continued in 1997 and 1998. This report summarizes the 1998 activities. Objectives of the 1998 study were:

- To provide an estimate of population in the McLeod/Whitehorse river system during the prenesting season using mark-resighting techniques.
- To identify the location of nest sites of Harlequin Ducks in the McLeod/Whitehorse river system using radio-telemetry techniques.
- To conduct a survey to identify brood presence and numbers in the McLeod/Whitehorse river system
- To determine a survival rate for Harlequin ducklings in the McLeod/Whitehorse river system using data from 1997 and 1998
- To implement and evaluate the long-term monitoring program for Harlequin Ducks in the McLeod River system.

The overall goal of this study is to develop a mitigation strategy and to make recommendations regarding a long term monitoring program to track the response of Harlequin Ducks to the Cheviot Mine development.

In 1998, 49 Harlequin Ducks were captured and newly banded in the Mcleod River watershed. There were 22 adults (14 males and 8 females) and 27 ducklings. In addition, nine females banded in previous years were recaptured and their worn bands replaced.

A prenesting survey of the McLeod River/Whitehorse Creek watershed was carried out May 28 and 29, 1998. The survey covered 54.5 km of the McLeod River (Mackenzie Creek to the Cardinal River Divide), Thornton, Harris, Prospect, and the lower portion of Whitehorse Creek (to the ford). It was estimated that there were 78±7 S.D. adult harlequins in the McLeod/Whitehorse system. This estimate was higher than the 1996 and 1997 estimates (58±7 S.D. and 62±6.2 S.D. adult birds). The male:female sex ratio was calculated from the May 1998 survey was 60:40. This means that in a population of 78 birds, 39 should be male, and 31 should be female. A sex ratio biassed toward males is common in the spring breeding grounds.

To establish the location of nests, 13 female harlequins were captured in May and early June, 1998 and were fitted with radio-transmitters attached to the underside of the tail feathers. Four nested successfully, two attempted to nest but failed and seven were non breeders. Three of the 13 birds lost their transmitters. In addition to the 13 radio-tagged hens there were 11 other female Harlequin Ducks observed in the system in 1998. Of these, five had successful nests, one had a failed nest and five did not attempt to nest. This brings the total number of successful nests to nine, the failed breeders to three and non breeders to 12.

The locations of nests were not necessarily proximate to pair locations. Capture sites represented areas where the birds were consistently found in May and early June. The nest locations of females White H7, Red 5S, Red 4L, White VP, Red 6U and Red 4A were located at a distance of 2.1, 4.9, 6.1, 10.0, 13.2 and 21.7 km respectively from their capture sites, an average of 9.7 km.

Nests were found on Whitehorse and Drummond Creek, and on the McLeod River above the confluence with Whitehorse Creek. One nest was found on each of Prospect, Harris and Unnamed "J" Creeks. Another hen was suspected of nesting on Unnamed "J" Creek. In 1998 as in 1997, no nests were found in Thornton, Cheviot, or Harlequin Creeks.

Brood surveys were conducted August 4, 5, 6, and 10, 1998. The presence of nine broods with 45 young was confirmed. During the survey, four broods were identified on the McLeod River upstream of Whitehorse Creek, four on Whitehorse and Drummond Creeks and one on the McLeod River downstream of Whitehorse Creek (unknown origin).
Prime brood rearing stretches were identified as:

- the main stem of the McLeod River from the McLeod River Canyon to the mouth of Harris Creek, and
- Whitehorse and Drummond Creeks.

One hen (Red 5S (rebanded as Red 7S) with a nest on Prospect Creek hatched eight ducklings and immediately moved them to the main stem of the McLeod River where she remained for the duration of brood rearing. The distribution of broods in 1998 was similar to the two previous years.

A total of 36 ducklings (18 in 1997 and 18 in 1998) survived to Class III from 50 hatched in the 8 broods with sufficient repeated observations to be included in calculations of duckling survival. Estimated interval survival rates for these broods for age classes from hatching to fledging ranged from 88% -100% for a span survival rate estimate of 72%. Slightly less than half of the duckling mortality (6 of 14 or 42.9%) occurred in the first interval (Class IA) which represents the first 4 days after hatching. Additional mortality occurred in Class IB (1 out of 14 or 7.1%), Class IIA (3 of 14 or 21.4%), Class IIB (3 of 14 or 21.4%) and Class IIC (1 of 14 or 7.1%). No mortality was observed in Class III ducklings.

A map and table updating the breeding status in the Cheviot area was prepared. New in 1998 was the identification of Unnamed "J" Creek as a breeding stream, and the upgrading of Harris Creek from probable breeding to breeding.

Components of a long-term monitoring program were discussed. The primary means of monitoring the population will be to conduct a spring survey in a systematic manner to estimate the number of adults (breeding potential), and to conduct a summer brood survey to identify the number of young produced in the system that survive to migrate to their wintering grounds (productivity).

Survey location and timing was discussed. Parameters generated from the spring survey will include: the number of adults present during prenesting period, sex ratio in the prenesting period, and distribution within the system. Parameters generated from the brood survey will include: number of broods produced, ratio of hens with broods to hens present in prenesting, average brood size (calculated early to mid-August; the last date when positive identification of broods in the system can be made), and distribution within the system.

Acknowledgments

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The photograph on the front cover is of a Harlequin Duck Class IIA duckling.

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THE 1998 CHEVIOT HARLEQUIN DUCK STUDY

1.0 INTRODUCTION

1.1 Background

To address unknowns identified in the environmental assessment prepared for the proposed Cheviot Mine, Cardinal River Coals Ltd. initiated a Harlequin Duck study in May 1996 which was continued in 1997. During these studies, 110 birds were captured and banded. Band data was sent to Washington State University and the Canadian Wildlife Service. Population estimates were made using mark-resighting techniques in 1996 and 1997. Distribution of harlequins throughout the summer was mapped using eight systematic surveys in 1996 and six in 1997. The breeding status of surveyed streams in the Cheviot area was updated. A chronology of harlequin activity on the McLeod River was developed, and used to identify seasonal concentration areas. The annual life cycle of the Harlequin Duck was described. Timing windows for construction activity were developed. Annual progress reports were produced and widely circulated.

1.2 1998 Purpose

In 1998, activities with respect to mitigating the effects of the Cheviot Mine on Harlequin Ducks will consist of implementing and evaluating the long term Harlequin Duck monitoring program and conducting a second year of locating nest sites by means of radio-tagging females. Should construction begin during the summer, a supplementary proposal will be submitted to describe additional activities e.g. monitoring construction activities etc.

1.3 1998 Objectives

- To provide an estimate of population in the McLeod/Whitehorse river system during the prenesting season using mark-resighting techniques.
- To identify the location of nest sites of Harlequin Ducks in the McLeod/Whitehorse river system using radio-telemetry techniques.
- To determine a survival rate for Harlequin ducklings in the McLeod/Whitehorse river system using data from 1997 and 1998.
- To conduct a survey to identify brood presence and numbers in the McLeod/ Whitehorse river system
- To implement and evaluate the long-term monitoring program for Harlequin Ducks in the McLeod River system.

2.0 STUDY AREA

The Cheviot Mine is located in the foothills of west central Alberta approximately 70 km south of the town of Hinton. The Cheviot Mine is drained by the McLeod River and its tributaries, Mackenzie Creek which flows into the McLeod River, and Redcap Creek which flows into the Cardinal River. The McLeod and Cardinal Rivers are separated by the Cardinal Divide. Water from the McLeod River flows north into the Arctic Ocean via the Athabasca River, Athabasca Lake, Slave and Mackenzie Rivers. Water from the Cardinal River flows south and east into Hudson's Bay via the North Saskatchewan River, Lake Winnipeg and Nelson Rivers. Streams in the study area flow through Subalpine, Montane and Upper Boreal ecoregions.

Elevation in the area decreases 628 metres from approx. 2,000 m at the McLeod River headwaters to approx 1,372 metres at the McLeod River below the confluence with Mackenzie Creek (elevations taken from1:50,000 NTS maps). This elevation decline can be broken down into the following sections:

Table 1. Stream section length and gradient, McLeod River.

McLeod River Section	Elevation Difference (m)	Distance (m)	% Slope
Cardinal Divide to the bridge on Grave Flats road immediately north of the Cardinal Divide	120	1,500	8.0
Bridge on Grave Flats road immediately north of Cardinal Divide to Harris Creek	140	4,750	2.9
Harris Creek to Prospect Creek	80	4,500	1.2
Prospect Creek to Whitehorse Creek (includes canyon)	60	2,300	2.6
Whitehorse Creek to Mackenzie Creek	228	20,000	1.1

In 1998, work was performed on the McLeod River, Luscar Creek, Whitehorse Creek, Drummond Creek, Harlequin Creek, Prospect Creek, Harris Creek, Thornton Creek, Cheviot Creek, Unnamed "J" Creek, Mackenzie Creek as well as the Cardinal River.

3.0 METHODS

In order to identify individual harlequins for population estimates, movements and habitat use, a capturing and banding program was initiated in 1996. When a duck is captured it is fitted with colour coded leg bands that can be read from a distance by an observer. Each combination of band colour with a letter code engraving is unique to each bird. The two digit engraved code can consist of either alpha-alpha, alpha-numeric, numeric-alpha or numeric-numeric characters. In the McLeod and Cardinal River watersheds, the band identification for the Harlequin Duck is a Red colour with White numeric-alpha characters. Figure 1 identifies capture and banding locations used in 1998.

Beginning in 1997 Harlequin Duck hens were also fitted with radio transmitters to allow for identification of nest sites. This was continued in 1998.

3.1 Banding and Radio-tagging

Capturing and banding of adults was deliberately started early in1998 and was conducted on May 15, 19-22, 26-29, June 5 and 12. Radio transmitters were attached to 13 females during the May banding session. Methods were similar to MacCallum and Bugera (1998). The banding of broods was carried out on August 18-21 and 27, 1998. During the August session, 27 ducklings were banded. Banding locations are identified in Figure 1.

3.2 Breeding Potential

To estimate the Harlequin Duck population (N), in the McLeod River and its tributaries in the prenesting period, a mark-resighting estimator based on a two-sample Lincoln-Petersen Index that was adjusted for bias by Chapman (1951) was used:

$$\hat{N} \text{ (population estimate)} = \left[\frac{(N_1+1)(N_2+1)}{(M_2+1)}\right] -1$$

where: N_1 = initial number of marked and released birds

N_2 = # of observed birds in subsequent samples for which status was determined. This included the marked birds.

M_2 = # of marked birds observed in subsequent sample.

$$\text{Variance } (S^2) = \frac{(N_1+1)(N_2+1)(N_1-M_2)(N_2-M_2)}{(M_2+1)^2(M_2+2)}$$

Standard Deviation = $\sqrt{S^2}$

Population estimate presented as: N $\pm$ S.D.

or N $\pm$ S.e. (S.e. = S.D./%N)

or with 95% Confidence Interval

The assumptions of the two-sample, mark-resighting method leading to the Lincoln Index are:

Lincoln Index (Skalski and Robson, 1992)

1. There are equal and independent capture probabilities for all animals within a sampling period.
2. Marking does not affect catchability (implied by assumption 1 above).
3. Animals do not lose their marks.
4. All marked animals captured in the second period are reported.
5. Animals are randomly sampled either in both periods, or systematically after random mixing of marked and unmarked animals.
6. Population of size N is closed, or alternatively, if mortality only is occurring, $\hat{N}$ estimates population abundance at time of first sample or if recruitment only is occurring $\hat{N}$ estimates population abundance at time of second sample; if both mortality and recruitment are occurring, $\hat{N}$ is invalid.

Lincoln-Petersen Model (Lancia et al. 1994)

1. The population is closed.
   Assumption of closed population usually can be met if the interval between samples is short.
   Assumption 6 of Lincoln Index.
2. All animals are equally likely to be captured in each sample.
   Assumptions 1 and 2 of Lincoln Index.
3. Marks are not lost, gained or overlooked.
   Assumptions 3 and 4 of Lincoln Index.

The prenesting survey was conducted by means of an instream foot survey on May 28 and 29, 1998 and was scheduled to coincide with an Alberta Environmental Protection/Canadian Wildlife Service helicopter survey for estimation of sightability error (Gregoire et al. in prep). Observers walked upstream in the water or on the bank while scanning the stream and its banks for birds. At each bend the observer would stop and scan the next stretch carefully before proceeding. Observers carried binoculars, spotting scopes and radios. All birds encountered were examined for bands and classified as: banded, unbanded or unknown. Birds classified as unknown were not used in the population estimate. The survey covered 54.5 km and consisted of portions of: the McLeod River (39.2 km beginning near Mackenzie Creek and ending near the Cardinal River Divide), Thornton Creek (2.9 km), Harris Creek (3.0 km), Prospect Creek (3.6 km), and the lower portion of Whitehorse Creek (5.8 km from the mouth to the ford).

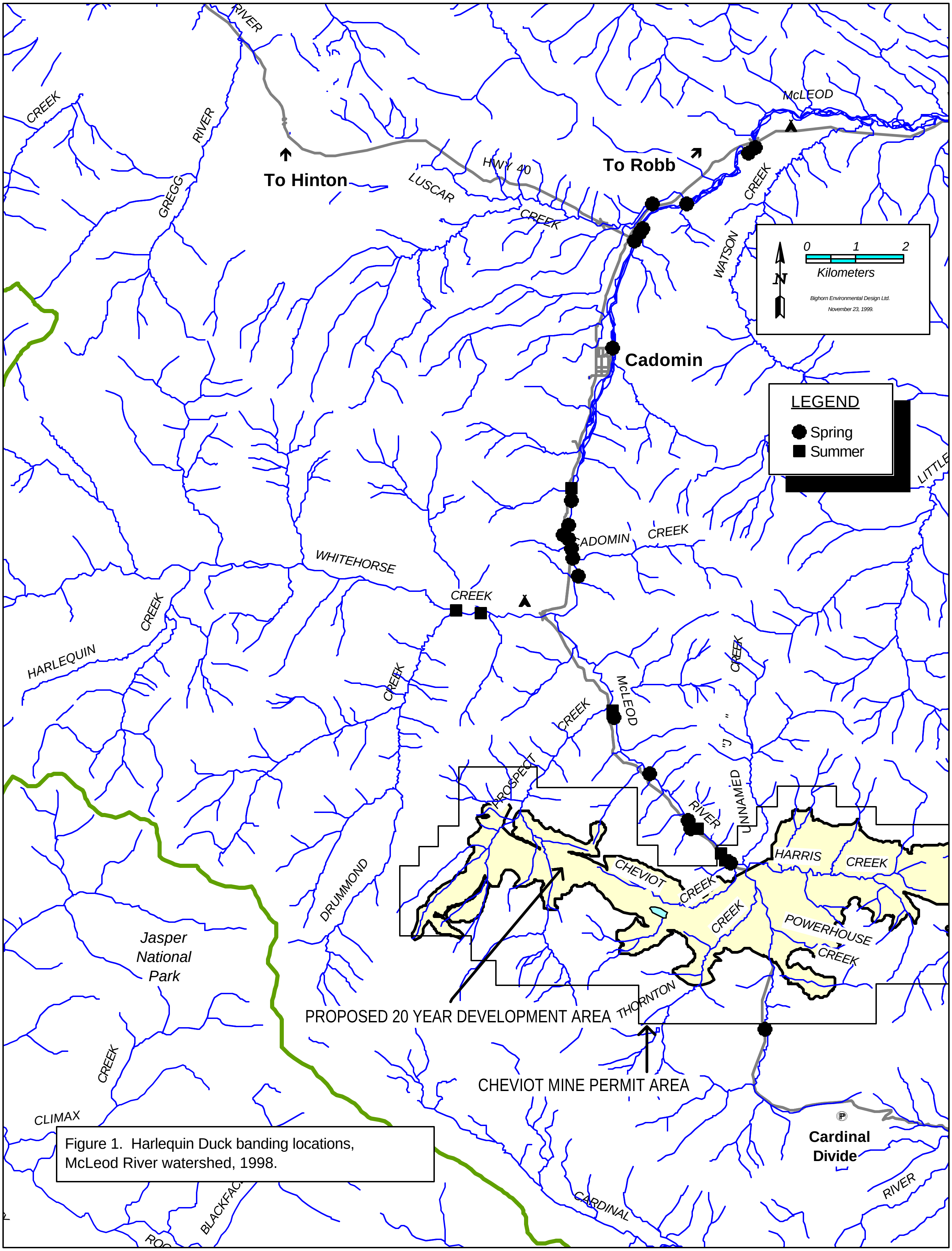

Figure 1. Harlequin Duck banding locations, McLeod River watershed, 1998.

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3.3 Brood Success

The August brood survey was carried out on August 4-6 and 10, 1998 and covered 47 km of the McLeod River/Whitehorse Creek system. These surveys were carried out in the same manner as the spring pair surveys where observers were each assigned a section of stream to walk looking for broods. Once a brood was sighted the number of ducklings and their stage of development was determined. Ages of ducklings were estimated (Figure 2) and placed into one of seven categories based on plumage development, colour and size (Table 2). All observations for the day were plotted on a 1:50,000 map.

Maps depicting the 1998 distribution of Harlequin Ducks in the McLeod watershed during the spring prenesting and summer brood surveys were prepared. To assist in the interpretation of results, a chronology of spatial and temporal distribution of Harlequin Ducks in the river system was compiled (Appendix I).

The stage of development of a duckling is determined visually using the general body shape and identification of feather development which is translated into seven classes originally developed for waterfowl by Gollop and Marshall in 1954 and adapted to Harlequins by Kuchel (1977), Wallen (1987) and Cassirer and Groves (1994). The different adaptations were developed by each investigator to reflect field observations of Harlequin duckling development in different geographical locations. Bellrose (1980) noted that environmental factors such as ambient temperature can cause variations in feather growth therefore it is possible that the variation in the age classes as noted in Figure 2 is based upon such factors as latitude and altitude. As all of the schemes were developed from locations at roughly the same latitude (Montana, Idaho and Wyoming) the altitude factor and how it relates to climate, determined that the Wallen (1987) scheme was chosen for this report. In addition to being the closest to the McLeod River and Whitehorse Creek in terms of upper elevation (2,135 m - Wallen, 2,000 m - McLeod/Whitehorse), the Wallen age classification scheme was used for a three year study on harlequins in the nearby Maligne River in Jasper National Park (pers. comm. W. Hunt).

Brood surveys were performed on a periodic basis to locate hens and to determine brood age and size. Repeated brood observations allowed for the calculation of duckling survival rates for age class intervals. Mayfield (1961 and 1975) developed the concept of a daily survival rate which is the probability that an animal alive at the beginning of a day will survive during that day (Heisey and Fuller 1985) and is the basis for the calculation of the age class and hatching to fledging survival rates. He recognised a problem which can arise when calculating a survival rate using a simple percentage of animals alive at the end of an interval divided by the number of animals alive at the beginning of the interval.

If animals, or in Mayfield's case nests, are not found at the beginning of the interval and subsequently die before being found, the survival rate for the interval is biassed upwards. In order to reduce this bias Mayfield calculated the daily survival rate by dividing the mortality days (number of known destroyed nests times the number of days in the interval) by the total exposure days (number of known nests multiplied by the interval length in days).

Figure 2. Harlequin duckling age classification schemes.

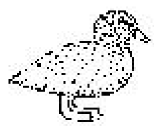
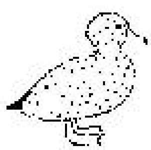
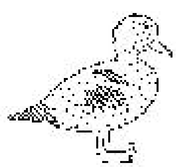
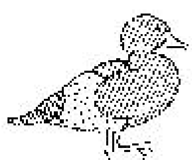
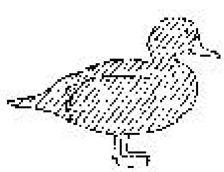
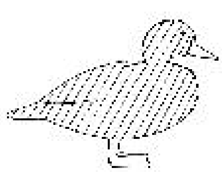
Age Class	Feather Development	Description	Kuchel (1977)	Wallen (1987)	Cassirer and Groves (1994)
			Days	Days	Days
IA		Young are down-covered	1 - 7	1 - 5	1 - 4
IB		Young down-covered, but colour fading	8 - 14	6 - 9	5 - 8
IC		Young down-covered, but colour faded, body elongated	15 - 20	10 - 14	9 - 14
IIA		First feathers appear, replacing down on sides and tail	21 - 25	15 - 21	15 - 25
IIB		Over half of body covered with feathers	26 - 38	22 - 27	26 - 30
IIC		Small amount of down remains, among feathers of back	39 - 45	28 - 35	31 - 35
III		Fully feathered but incapable of flight	46 - 52	36 - 42	36 - 51

Table 2. Guide to aging broods for the Harlequin Duck (after Gollop and Marshall 1954 modified by Wallen 1987).

CLASS I Downy Young	CLASS II Partly Feathered	CLASS III Fully Feathered
A) Bright Ball of Fluff (1 - 5 days) Down bright. Patterns distinct (except diving ducks). Body rounded; neck and tail not prominent.	A) First Feathers (15 - 21 days) First feathers show on side under ideal field conditions. Stays in this class until side view shows one half of side and flank feathered.	Feathered-flightless (38 - 42 days) No down visible. Primaries completely out of sheaths but not fully developed. Stays in this class until capable of flight.
B) Fading Ball of Fluff (6 - 9 days) Down colour fading; patterns less distinct. Body still rounded; neck and tail not yet prominent.	B) Mostly Feathered (22 - 27 days) Side view shows one half of side and flank feathered. Primaries break from sheaths. Stays in this class until side view shows down in one or two areas only (eg. nape, back or upper rump).	
C) Gawky-downy (10 - 14 days) Down colour and patterns faded. Neck and tail become prominent. Body becomes long and oval	C) Last Down (28 - 35 days) Side view shows down in one or two areas only (nape, back, or upper rump). Sheaths visible on erupted primaries through this class. Stays in this class until profile shows no down.	

3.4 Duckling Survival Rates

The daily survival rate is assumed to be constant within each interval and allows for the variability in age class (interval) length. Once the daily survival rate is obtained, the interval (age class) survival rate becomes the daily survival rate to the power of the interval length and the span (hatching to fledging) survival rate is the product of all of the interval rates (Heisey and Fuller 1985).

For comparison purposes several methods were used to calculate harlequin duckling daily survival rates including *Micromort v1.3* (Heisey and Fuller 1985), Mayfield 1975 (in Bart and Robson 1982), and a maximum likelihood estimator (Bart and Robson 1982). In addition, a simple percentage interval survival rate was calculated. Eight broods (4 in 1997 and 4 in 1998) had sufficient observational data, (ie. $ 4 intervals with direct observations) to allow for interpretation. Five broods with missing observation data were completed using interval survival rates generated from the 3 broods with complete data (see Section 4.8).

3.4.1 Micromort

Micromort uses a Mayfield formula as described by Heisey and Fuller where the daily survival rate (s_i) was calculated by dividing the total exposure of all ducklings (in duckling-days, n = 2101) into seven intervals (age classes) and then dividing each resulting interval duckling-day total (x_i) minus the total interval mortality (y_i) by the interval duckling-days total (x_i) (Heisey and Fuller 1985).

$$\hat{s}_i = \frac{x_i - y_i}{x_i}$$

Table 3. Definition of variables used in Micromort model to calculate duckling survival. (After Heisey and Fuller, 1985).

i	=	Interval number (i - IA, IB, ...III)
x_i	=	Total number of duckling-days during interval i
y_i	=	Total number of mortalities occurring during interval i
l_i	=	Total number of days in interval i
s_i	=	Daily survival rate during interval i
S_i	=	Interval survival rate for entire interval i
S*	=	Span survival rate for all I intervals

3.4.2 Mayfield Daily Survival Rate Estimate

Mayfield (1975 in Bart and Robson 1982) describes a model where the daily survival estimate ($\hat{p}_m$) equals 1 - the estimated daily mortality rate. The estimated daily mortality rate is calculated by dividing the number of deaths in a given interval by the number of days that living subjects were observed. The number of days that living subjects were observed is calculated by multiplying the number of survivors plus a fraction of the fatalities by the interval length. Mayfield used 50% as the fraction which assumes that the mortality occurred midway through the interval while Miller and Johnson argue that 40% is more appropriate for waterfowl studies which tend to have longer interval periods, often 20 days or more (Miller and Johnson 1978)(Johnson 1979) and (Bart and Robson 1982).

This study of Harlequin ducklings used interval lengths of 4 - 8 days which is more similar to the interval length of 1 - 6 days noted by Mayfield for Kirkland's Warblers than that noted by Miller and Johnson (1978) and Johnson (1979) for ducks therefore the 50% fraction is more appropriate for calculations here (Klett and Johnson 1982). The formula is

$$\hat{p}_m = 1 - \frac{\text{number of deaths}}{l(n_{ls} + hn_{lf})}$$

Table 4. Definition of variables in Mayfield (1975) estimate of daily survival rate

l	=	Interval length in days
L	=	Maximum interval length
n_{ls}	=	Number of intervals of length l in which mortality did not occur
n_{lf}	=	Number of intervals of length l in which mortality occurred
h	=	Fraction

3.4.3 Maximum Likelihood Estimator

A maximum likelihood estimator (MLE) is the true daily survival rate which can be used to test for a statistically significant difference between two populations (Bart and Robson 1982). Although this study of Harlequin duckling survival includes only one population, an MLE can be used to provide an accurate daily survival rate.

When the intervals are of varying length the MLE calculations require three steps. Step one is covered by the Mayfield formula as in section 3.4.2 to calculate $\hat{p}_m$ which is then used in step two to calculate $f(\hat{p}_m)$ and $f^1(\hat{p}_m)$.

$$f(\hat{p}_m) = \sum_{l}^{L} \frac{l}{\hat{p}_m}(n_{ls} - \frac{n_{lf}\hat{p}_m{}^l}{1-\hat{p}_m{}^l})$$

$$f^1(\hat{p}_m) = \sum_{l}^{L} \frac{l}{\hat{p}_m{}^2}(\frac{n_{ls} + n_{lf}\ \hat{p}_m{}^l\left(l-1+\hat{p}_m{}^l\right)}{(1-\hat{p}_m{}^l)^2})$$

Step three of the MLE calculation process uses $f(\hat{p}_m)$ and $f^1(\hat{p}_m)$ to calculate $\hat{p}_0$ which is the true daily survival rate.

$$\hat{p}_0 = \hat{p}_m + \frac{f(\hat{p}_m)}{f^1(\hat{p}_m)}$$

3.4.4 Interval Survival and Span Survival Rate

Once the estimated daily survival rate is established by one of the methods described above the interval survival rate, or in this case the age class survival rate, (S_i) is calculated by taking the daily survival rate (s_i, $\hat{p}_m$ or $\hat{p}^0$) to the power of the number of days in the interval (l_i).

$$\hat{S}_i = \hat{s}_i^{\,l_i}$$

The combined value (span survival rate) is the product of the estimated interval survival rates

$$\hat{S}^* = \prod_{i=1}^{I} \hat{S}_i$$

3.5 Nest Site Location

The location of nest sites was identified by attaching radio transmitters to the underside of the tail feathers of 13 females during the May capturing and banding session. This method of attachment has proven to be reliable with a low risk of mortality (R. Jarvis pers. comm.1997, MacCallum and Bugera 1998). Females were followed on the ground to find their nest sites, and then monitored weekly. Helicopter surveys were conducted June 12 to identify remote nest sites and were continued biweekly on June 20, July 1 and July 10. Nests used in 1997 were checked for occupancy. Nest site locations were plotted and habitat information obtained. Nests were monitored prior to hatching as well as the broods immediately after hatching.

3.6 Long-term Monitoring Program

Results from the 1995-1998 Cheviot Harlequin Duck program will be used to refine the long term monitoring program to be conducted during the Cheviot project. These results will be used to make recommendations on the timing of surveys, the location of surveys and other work required to support the survey information. Population characteristics which are relevant to understanding the health of the harlequin population will be identified.

4.0 RESULTS

4.1 Banding Summary

In 1998, 49 Harlequin Ducks were captured and banded on the McLeod River watershed, These were comprised of 22 adults (14 male, 8 female) and 27 ducklings (12 female, 14 male). In addition, nine females that were banded in previous years were captured and their worn bands replaced with new bands. One of these previously marked birds (Red 9R, formerly Green BD) was banded at Cape Lazo at Comox BC, and another (Red 9Z, formerly 8Z) which was banded on the McLeod River in 1996 was observed on several occasions at Boundary Bay, Whiterock BC.

4.2 Nesting Status

Of 13 female harlequins that were fitted with radio transmitters in 1998, four nested successfully, two attempted to nest but failed and seven were non breeders. Three of the 13 birds lost their transmitters.

In addition to the 13 radio-tagged hens there were 11 other female Harlequin Ducks observed in the system in 1998. Of these, five had successful nests, one had a failed nest and five did not attempt to nest. This brings the total number of successful nests to 9, the failed breeders to 3 and non breeders to 12.

4.3 Spring Population Estimate

The banding and surveying session between May 15 and 29 was used to estimate the number of birds in the McLeod River and its tributaries in the spring of 1998. The last week of May and first week of June is the period of maximum sightability of females in the McLeod system (MacCallum and Bugera 1998). Females may be nesting and laying eggs at this time but with few exceptions, incubation has not started. There were a total of 35 banded ducks identified in the system by May 29. During the May 28/29 survey, 55 ducks were observed, 23 of which were banded, 29 were unbanded and 3 unknown. Birds designated as unknown were not used in the calculation for the population estimate.

The majority of ducks (31 of 55) recorded during the two day survey were observed in the stretch between the Watson Creek campground on the McLeod River and the ford on Whitehorse Creek. This figure consisted of 20 males and 11 females. Fifteen ducks (8 males and 7 females) were observed on the lower McLeod River between the CN bridge downstream of Mackenzie Creek and Watson Creek campground. Nine ducks (4 males and 5 females) were observed on the upper McLeod River between the mouth of Whitehorse Creek and the Grave Flats Road bridge below the Cardinal Divide. This survey stretch also included Prospect, Harris and Thornton Creeks (Figure 4).

The population estimate for the McLeod/Whitehorse Creek system between May 28-29 was 78.5 ± 6.8 ducks (S.D.) (Table 5). The male:female sex ratio was calculated from the May 28-29 survey was 1.4:1 (78.5 males:56 females). This means that in a population estimate of 78 adult birds, 47 should be males and 31 should be females. In the spring, a sex ratio biassed towards males is common.

4.4 Nest Locations

In 1998 Harlequin Duck nests were found on Whitehorse, Drummond, Prospect, Harris and Unnamed "J" Creeks as well as on the McLeod River (Figure 3). As in 1997, no nests were found on the McLeod River downstream of the confluence of Whitehorse Creek. Of the 12 hens who had nests (breeders and failed breeders) two were on Whitehorse Creek, one was on Drummond Creek, two were on Unnamed "J" Creek (one suspected, one confirmed), one was on Harris Creek, one was on Prospect Creek and one was on the McLeod River. Four nest locations were unknown. No nests were found on Harlequin, Thornton or Cheviot Creeks in 1998.

The locations of nests were not necessarily proximate to pair locations. Capture sites represented areas where the birds were consistently found in May and early June. The nest locations of females White H7, Red 5S, Red 4L, White VP, Red 6U and Red 4A were located at a distance of 2.1, 4.9, 6.1, 10.0, 13.2 and 21.7 km respectively from their capture sites, an average of 9.7 km.

Table 5. 1998 estimate of Harlequin Duck population for the McLeod River

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To estimate the Harlequin Duck population (N), of the McLeod River and its tributaries, a mark-resighting estimator based on a two-sample study was chosen. Known as the Lincoln-Petersen estimator (Lincoln 1930), it was revised by Chapman (1951) to provide less bias. Seber (1970) provided an unbiased estimate of the variance of N. Results from the May 15, 19-22, 26 and 27, 1998 banding session (first sample) and the May 28 - 29, 1998 McLeod River/Whitehorse Creek survey (second sample) were used with the revised (unbiased) formula:

$$\hat{N} \text{ (population estimate)} = \left[\frac{(N_1+1)(N_2+1)}{(M_2+1)}\right] - 1$$

where: N_1 = 35 (initial number of marked and released birds)
N_2 = 52 (# of observed birds in subsequent samples for which status was determined. This included the marked birds).
M_2 = 23 (# of marked birds observed in subsequent sample).

$$\text{Variance } (S^2) = \frac{(N_1+1)(N_2+1)(N_1-M_2)(N_2-M_2)}{(M_2+1)^2(M_2+2)}$$

Standard Deviation = $\sqrt{S^2}$
Population estimate: = 78.5 ± 6.8

Note: Sex Ratio = 60**%**:40**&**; then estimated actual numbers = 47**%** and 31 **&**.

For application of the Lincoln-Petersen Index to the conditions found in the prenesting period on the McLeod River, the population was assumed to be closed and the following additional assumptions were made:

- No mortality occurs between the first sample and second sample which is separated in time by no more than one week
- Surveys of different stream reaches are conducted simultaneously or consecutively in a systematic manner. Birds observed in consecutive reaches are assumed to be different birds unless they are known to have been observed in the previous reach
- Birds comprising the marked (first) sample included birds banded May 15, 19-22, 26 and 27, 1998 in the McLeod River watershed as well as those birds that had been banded in previous years that were observed in 1998 prior to and during the survey (May 28 and 29).
- Young of the year from the previous year (1997) are assumed to have remained on the coast and do not compromise part of the first or second sample of the survey year.
- Marked birds known to be present in the system in previous years but not found in the system in the survey year are assumed to have died or emigrated.

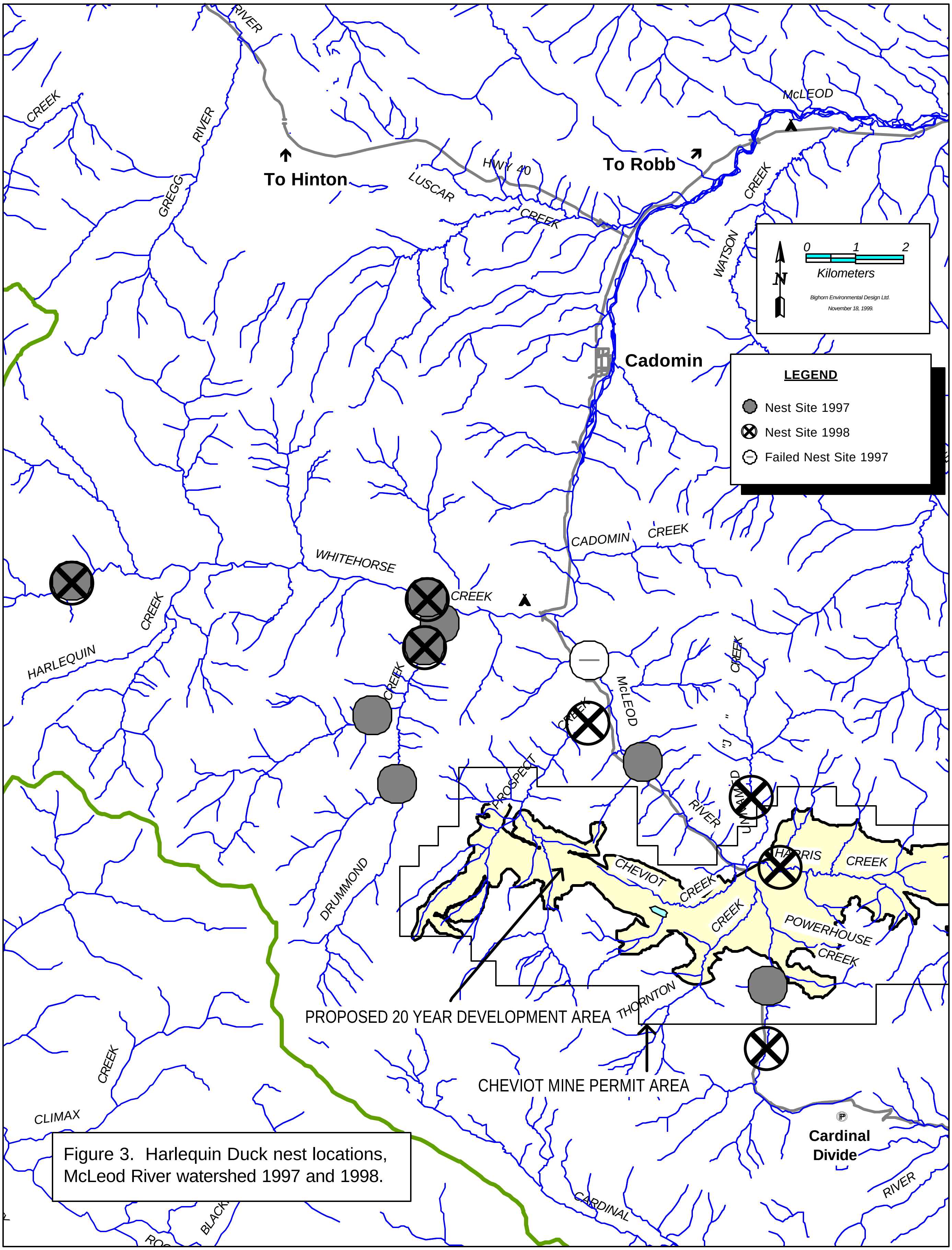

Figure 3. Harlequin Duck nest locations, McLeod River watershed 1997 and 1998.

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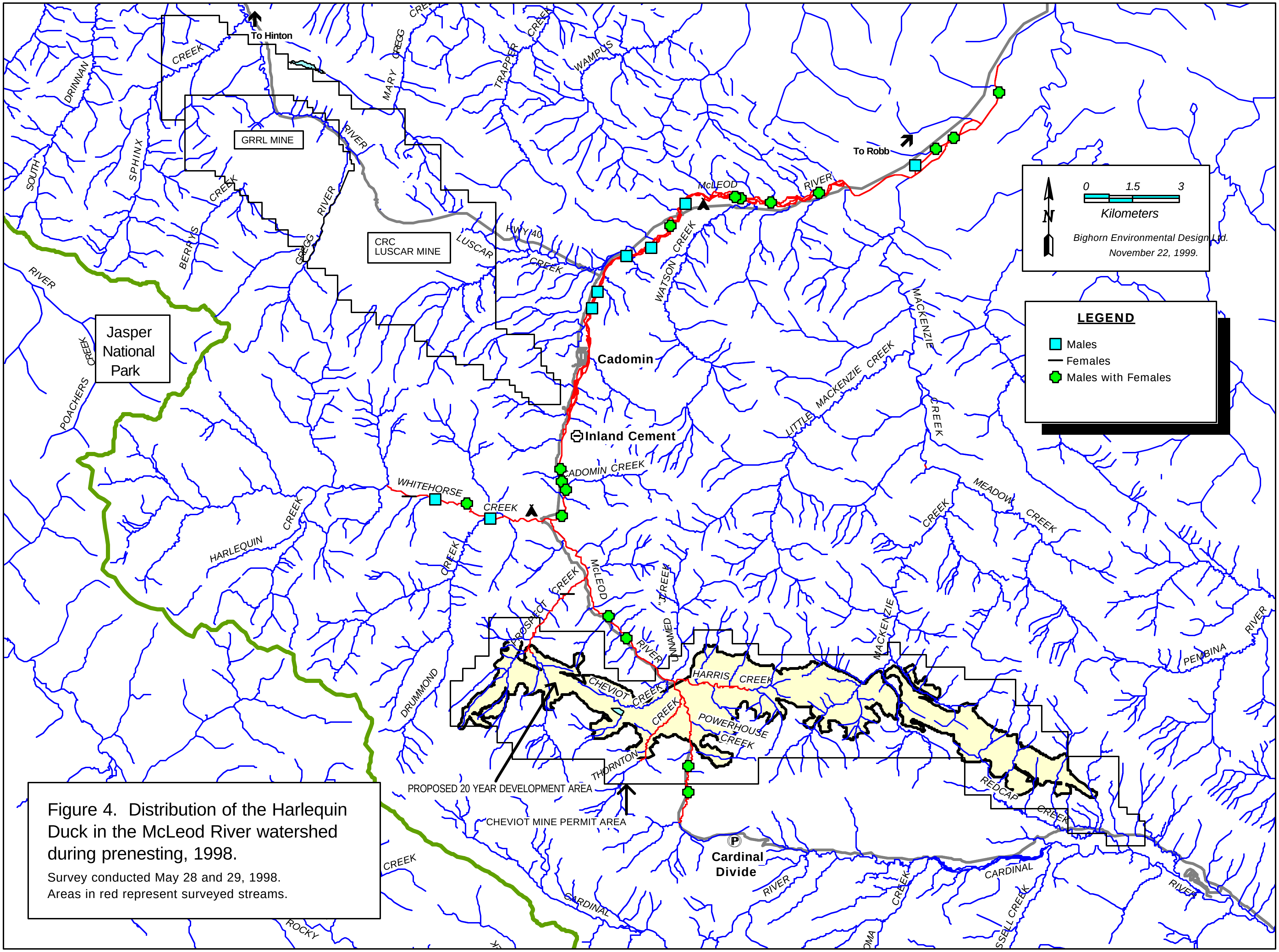

Figure 4. Distribution of the Harlequin Duck in the McLeod River watershed during prenesting, 1998.

Survey conducted May 28 and 29, 1998.
Areas in red represent surveyed streams.

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4.5 <u>Incubation</u>

Using the Wallen (1987) duckling age classification scheme, the median start date for incubation in 1998 was estimated as June 15 (range June 4 - July 1, n=9) by backdating from the median hatch date of July 12 (range July 1 - July 28) and by assuming incubation to be 28 days (Table 6). These dates are similar to those generated by using the Cassirer and Groves (1996) age classification scheme (median start date for incubation = June 15 (range June 4 - June 26, n=9); median hatch date = July 11 (range July 1 - July 23). The median start date for incubation in 1998 (June 15) was similar to incubation initiation in 1997 (June 13, range June 5 - June 19) but earlier than those reported in 1996 (June 28, range June 13 - July 18). The median hatch date in 1998 (July 12) was similar to 1997 (July 12, range July 4 - July 18) but earlier than 1996 (July 25, range July 10 - August 14).

Table 6. 1998 estimated hatching and incubation dates for the Harlequin Duck in the McLeod River watershed based on back-dating brood ages (Wallen 1987).

Hen	Date First Observed on Nest	First Date Brood Observed 1998	Brood Class	Age at Sighting (days)	Estimated Hatch Date, Median and (Range)	Estimated Incubation Initiation, Median and (Range)
Red 8T (Red 7T)		July 2	IA	2+	July 1	June 4
Red 5S (Red 7S)	May 28	July 5	IA	2#	July 4	June 7
White H7 (Red 6V)	June 13	July 13	IA	1 - 3*	July 12 (11-13)	June 15 (14-16)
White VP (Red 7P)		July 13	IB	5 - 8	July 6 (5-8)	June 10 (9-12)
Red 5G (Red 6X)		August 3	IIB	25 - 35	July 10 (8-13)	June 14 (12-17)
Red 5P (Red 6Z)		August 4	IIA	15 - 25	July 18 (15-21)	June 19 (17-22)
Red 9S		August 18	IIB	25 - 35	July 25 (23-28)	June 29 (June 27-July1)
Red 7R		August 21	IIB	25 - 35	July 28 (26-31)	July 1 (June 30-July 4)
Red 1G		August 27	III	36 - 51	July 20 (17-23)	June 24 (21-27)

\+ = Eight fresh membranes found in nest July 2
* = Observed on nest July 10   # = Observed on nest July 3
() = band colour and code replacing original band which had become worn and unreadable.

4.6 Hatching

Table 6 indicates estimated incubation initiation dates in 1998 as well as estimated hatch dates from the estimated age at date of first sighting (Wallen 1987). Backdating was not used for two broods for which observations were accepted as being within one day of hatching. Red 5S was observed with eight downy young on July 5 on Prospect Creek. Red 5S had been observed incubating her eggs on the nest July 3. Hatch date was identified as July 4. The nest of Red 8T was found empty on Whitehorse Creek on July 2, 1998. Fifty-one days later she was observed on August 21 with three Class III young. Hatch date was identified as July 1.

The first brood observed in 1998 (July 2) was similar to the date of the first brood observed in 1997 (July 9) but earlier than the first observations of 1996 (July 19) and 1995 (July 20). Survey timing in 1995 and 1996 was based on results obtained from harlequin studies in the Maligne River (pers. comm. B. Hunt) while survey dates in 1997 and 1998 were based on the knowledge gained from the 1995 and 1996 McLeod River study.

In 1996 we were still designing our surveys after phenology provided to us by Jasper Park. Except for a few days of incidental surveys we did not systematically survey between June 28 and July 15 in 1996. In 1997 and 1998 we were using radio-telemetry techniques to find the nest sites so had a survey advantage over 1996 which was based on observation techniques alone. The median hatch date in 1998 was July 11 (range July 1 - July 23) n=9.
This is similar to 1997 (July 12, range July 4 - July 18), but earlier than 1996 (July 25, range July 10 - August 14). The 1996 date may reflect survey technique changes more than actual annual variation.

4.7 Number of Broods

In 1998, nine broods with 47 ducklings were confirmed to be present in the McLeod/Whitehorse Creek system. The first sightings of broods in 1998 were:

McLeod River above mouth of Whitehorse Creek:

- July 5 **&** *Red 5S (Red 7S)with 8 Class IA ducklings (nest site known)*
- July 13 **&** *White H7 (Red 6V) with 6 Class IA ducklings (nest site known)*
- July 21 **&** *Red 5P (Red 6Z) with 7 ducklings (nest site unknown)*
- August 3 **&** *Red 5G (Red 6X) with 1 Class IIB duckling (nest site unknown)*

McLeod River downstream of Whitehorse Creek:

- August 27 **&** *Red 1G with 5 Class III ducklings (nest site unknown)*

Whitehorse Creek:

- July 2 **&** *Red 8T (signs of recent hatching in nest; 8 membranes)*
- July 13 **&** *White VP (Red 7P) with 4 Class IB ducklings (nest site known)*
- August 18 **&** Red 9S with 3 Class IIB ducklings (nest site unknown)
- August 21 **&** Red 7R with 5 Class IIB ducklings *(nest site unknown)*

In 1998 the average brood size on the upper McLeod River/Whitehorse Creek was 5.2 young per successful hen (n = 9 broods). This figure is based on the first observation in July or August of the marked hen and her young, and includes any mortality suffered between hatch date and the date of first sighting (see list above). The 1998 average brood size for the system was similar to the average brood size in 1997 (5.1 young, n=9 broods) and 1996 (5.1 young, n=11 broods) (MacCallum and Bugera 1998 and MacCallum 1997). Brood size in the McLeod River system is similar to the average size of broods at hatching (5.1 young, n=16 broods) in the Central Cascade Mountains of Oregon in 1994 and 1995 (Bruner 1997).

During the 1998 brood survey, four broods were identified on the McLeod River above the canyon falls and four broods were identified on Whitehorse Creek and its tributaries. One brood was identified on the McLeod River downstream of Cadomin but it was not known which system they were hatched from (Figure 5).

In 1998 it was estimated that 31 females produced 9 broods (29% of females produced broods). The 1997 estimate was 24 females producing 9 broods (38% of females produced broods); and in 1996 it was estimated that 28 females present in the spring in the McLeod/Whitehorse system produced 11 broods (39% of females produced broods). The number of confirmed broods associated with the McLeod River and Whitehorse Creek and their tributaries have been similar in 1996 and 1997 (four broods in the McLeod in both years and seven and five broods in Whitehorse Creek in respective years). A total of 102 ducklings were hatched in 1996, 1997 and 1998 from 20 nests in the McLeod/Whitehorse system (43 ducklings on the McLeod, and 59 ducklings on Whitehorse).

4.8 Duckling Survival

Daily survival rates were calculated in Table 9 for the three broods (1997 Red 3S and 1998 White H7 and White VP) which had observations falling into every age class (in bold in Tables 7 and 8). The resulting age class survival rates were applied to five additional broods (1997 Red 2J, Red 3F, Red 6U and 1998 Red 5S, Red 5P) in order to calculate the probable brood size. Broods with less than four actual age class sightings were not used in the calculations.

Table 10 shows the results of the various methods of daily survival rate calculation and the resulting interval and span survival rates. The difference between the interval survival rates obtained by the different methods is <1% in all intervals. The small difference could be a result of the relatively small number of individual ducklings involved (n=50) or the short interval length or a combination of both. Survival rates ranged from the highest generated by Micromort to the lowest generated by Mayfield with the simple percentage and the MLE identical in the middle (all figures rounded to four decimal places).

Micromort generates estimates of daily, interval and span survival rates within 95% confidence limits (Table 11) and all of the figures generated by all of the methods fall within these confidence limits. For these reasons the maximum likelihood estimator method was used in this report to obtain age class and span (hatching to fledging) survival rates.

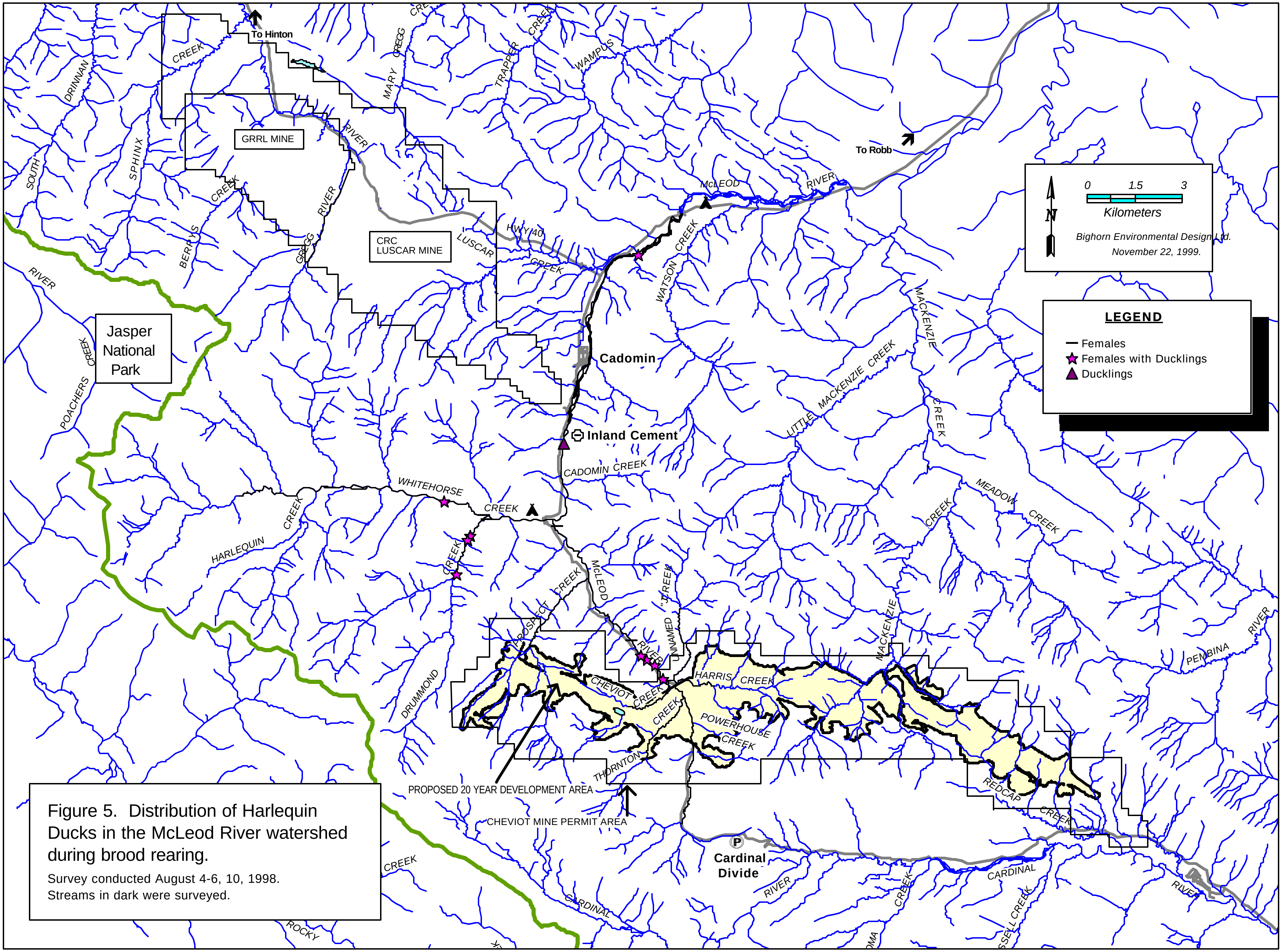

Figure 5. Distribution of Harlequin Ducks in the McLeod River watershed during brood rearing.

Survey conducted August 4-6, 10, 1998.
Streams in dark were surveyed.

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Table 7. 1997 age class duckling numbers using Wallen (1987)

Age Class	Days	No of days in interval	Red 8T (Red 7T)	Number of young	Red 2J	Number of young
IA	1 - 5	5	July 9 -13	8	July 5 - 9	5
IB	6 - 9	4	July 14 - 17		July 10 - 13	5
IC	10 - 14	5	July 18 - 22		July 14 - 18	5
IIA	15 - 21	7	July 23 - 29		July 19 - 25	5
IIB	22 - 27	6	July 30 - Aug 4		July 26 - 31	4
IIC	28 - 35	8	Aug 5 - 12		Aug 1 - 8	4.0
III	36 - 42	7	Aug 13 - 19		Aug 9 - 15	4.0

Age Class	Days	No of days in interval	**Red 3S**	**Number of young**	Red 3F	Number of young
IA	1 - 5	5	July 12 - 16	**6**	July 4 - 8	5.0
IB	6 - 9	4	July 17 - 20	**6**	July 9 - 12	4.0
IC	10 - 14	5	July 21 - 25	**6**	July 13 - 17	4
IIA	15 - 21	7	July 26 - Aug 1	**6**	July 18 - 24	4
IIB	22 - 27	6	Aug 2 - 7	**6**	July 25 - 30	3
IIC	28 - 35	8	Aug 8 - 15	**6**	July 31 - Aug 7	3
III	36 - 42	7	Aug 16 - 22	**6**	Aug 8 - 14	3.0

Age Class	Days	No of days in interval	Red 5P (Red 6Z)	Number of young	Red 6U	Number of young
IA	1 - 5	5	July 19 - 23		July 15 - 19	6
IB	6 - 9	4	July 24 - 27		July 20 - 23	6
IC	10 - 14	5	July 28 - Aug 1		July 24 - 28	6
IIA	15 - 21	7	Aug 2 - 8	6	July 29 - Aug 4	6.0
IIB	22 - 27	6	Aug 9 - 14		Aug 5 - 10	6.0
IIC	28 - 35	8	Aug 15 - 22	5	Aug 11 - 18	6.0
III	36 - 42	7	Aug 23 - 29	5	Aug 19 - 25	5

Age Class	Days	No of days in interval	Red 4L (Red 9N)	Number of young	White VP (Red 7P)	Number of young
IA	1 - 5	5	July 21 - 25		July 12 - 16	
IB	6 - 9	4	July 26 - 29		July 17 - 20	
IC	10 - 14	5	July 30 - Aug 3		July 21 - 25	3
IIA	15 - 21	7	Aug 4 - 10		July 26 - Aug 1	
IIB	22 - 27	6	Aug 11 - 16	6	Aug 2 - 7	
IIC	28 - 35	8	Aug 17 - 24	6	Aug 8 - 15	
III	36 - 42	7	Aug 25 - 31		Aug 16 - 22	

Figures in bold were used in Table 9.
Figures to 1 decimal place were generated from Maximum Likelihood Estimated Interval Survival Rate $(p_0)^I$ in Table 9

Table 8. 1998 age class duckling numbers using Wallen (1987)

Age Class	Days	No of days in interval	Red 8T (Red 7T)	Number of young	Red 5S (Red 7S)	Number of young
IA	1 - 5	5	July 1 - 5		July 4 - 8	8
IB	6 - 9	4	July 6 - 9		July 9 - 12	7
IC	10 - 14	5	July 10 - 14		July 13 - 17	6
IIA	15 - 21	7	July 15 - 21		July 18 - 24	6.0
IIB	22 - 27	6	July 22 - 27		July 25 - 30	5
IIC	28 - 35	8	July 28 - Aug 4		July 31 - Aug 7	5
III	36 - 42	7	Aug 5 - 11	3	Aug 8 - 14	5

Age Class	Days	No of days in interval	**White H7 (Red 6V)**	**Number of young**	Red 5G (Red 6X)	Number of young
IA	1 - 5	5	July 12 - 16	**6**	July 10 - 14	
IB	6 - 9	4	July 17 - 20	**5**	July 15 - 18	
IC	10 - 14	5	July 21 - 25	**5**	July 19 - 23	
IIA	15 - 21	7	July 26 - Aug 1	**5**	July 24 - 30	
IIB	22 - 27	6	Aug 2 - 7	**5**	July 31 - Aug 5	1
IIC	28 - 35	8	Aug 8 - 15	**5**	Aug 6 - 13	
III	36 - 42	7	Aug 16 - 22	**5**	Aug 14 - 20	

Age Class	Days	No of days in interval	Red 5P (Red 6Z)	Number of young	Red 9S	Number of young
IA	1 - 5	5	July 18 - 22	7	July 25 - 29	
IB	6 - 9	4	July 23 - 26	7	July 30 - Aug 2	
IC	10 - 14	5	July 27 - 31	7	Aug 3 - 7	
IIA	15 - 21	7	Aug 1 - 7	7	Aug 8 - 14	
IIB	22 - 27	6	Aug 8 - 13	7.0	Aug 15 - 20	3
IIC	28 - 35	8	Aug 14 - 21	4	Aug 21 - 28	
III	36 - 42	7	Aug 22 - 28	4	Aug 29 - Sept 4	

Age Class	Days	No of days in interval	Red 7R	Number of young	Red 1G	Number of young
IA	1 - 5	5	July 28 - Aug 1		July 20 - 24	
IB	6 - 9	4	Aug 2 - 5		July 25 - 28	
IC	10 - 14	5	Aug 6 - 10		July 29 - Aug 2	
IIA	15 - 21	7	Aug 11 - 17		Aug 3 - 9	
IIB	22 - 27	6	Aug 18 - 23	5	Aug 10 - 15	
IIC	28 - 35	8	Aug 24 - 31		Aug 16 - 23	
III	36 - 42	7	Sept 1 - 7		Aug 24 - 30	5

Age Class	Days	No of days in interval	**White VP (Red 7P)**	**Number of young**
IA	1 - 5	5	July 6 - 10	**7**
IB	6 - 9	4	July 11 - 14	**4**
IC	10 - 14	5	July 15 - 19	**4**
IIA	15 - 21	7	July 20 - 26	**4**
IIB	22 - 27	6	July 27 - Aug 1	**4**
IIC	28 - 35	8	Aug 2 - 9	**4**
III	36 - 42	7	Aug 10 - 16	**4**

Figures in bold were used in Table 9.
Figures to 1 decimal place were generated from Maximum Likelihood Estimated Interval Survival Rate $(p_0)^I$ in Table 9

Table 9. 1997 Red 3S and 1998 White H7 and White VP (Maximum Likelihood Estimated Interval Survival figures used to generate survival figures for Tables 7, 8 and 10)

Age Class	No. of days in interval (age class) $l = L_i$	Total number of ducklings per interval n_l	Total interval days $l n_l = x_i$	Survivors n_{ls}	Survival days $l n_{ls}$	Fatalities $n_{lf} = y_i$	Fatality days $l n_{lf}$	Simple Percentage Interval Survival Rate n_{ls}/n_l	Micromort Daily Survival Rate (Heisey & Fuller, 1985) s_i	Micromort Estimated Interval Survival Rate S_i	Mayfield Daily Daily Survival Rate Bart & Robson 1982 p_m	Mayfield Estimated Interval Survival Rate $(p_m)^l$	$f(p_m)$	$f^1(p_m)$	Maximum Likelihood Estimate Bart & Robson 1982 p_0	Estimated Interval Survival Rate $(p_0)^l$
IA	5	19	95	15	75	4	20	0.7895	0.9579	0.8065	0.9529	0.7858	8.4726	9442.2132	0.9538	0.7895
IB	4	15	60	15	60	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
IC	5	15	75	15	75	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
IIA	7	15	105	15	105	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
IIB	6	15	90	15	90	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
IIC	8	15	120	15	120	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
III	7	15	105	15	105	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
Total	42		650		630	4	20	***S**** = 0.7895	***S**** =	0.8065	***S**** =	0.7858			***S**** =	0.7895

Table 10. 1997 Red 2J, Red 3S, Ref 3F, Red 6U and 1998 Red 5S, White H7, White VP and Red 5P (Used to generate the Micromort data)

Age Class	No. of days in interval (age class) $l = L_i$	Total number of ducklings per interval n_l	Total interval days $l n_l = x_i$	Survivors n_{ls}	Survival days $l n_{ls}$	Fatalities $n_{lf} = y_i$	Fatality days $l n_{lf}$	Simple Percentage Interval Survival Rate n_{ls}/n_l	Micromort Daily Survival Rate (Heisey & Fuller, 1985) s_i	Micromort Estimated Interval Survival Rate S_i	Mayfield Daily Daily Survival Rate Bart & Robson 1982 p_m	Mayfield Estimated Interval Survival Rate $(p_m)^l$	$f(p_m)$	$f^1(p_m)$	Maximum Likelihood Estimate Bart & Robson 1982 p_0	Estimated Interval Survival Rate $(p_0)^l$
IA	5	50	250	44	220	6	30	0.8800	0.9760	0.8856	0.9745	0.8787	13.8010	47177.6516	0.9748	0.8800
IB	4	44	176	43	172	1	4	0.9773	0.9943	0.9775	0.9943	0.9772	1.9826	121800.9593	0.9943	0.9773
IC	5	43	215	43	215	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
IIA	7	43	301	40	280	3	21	0.9302	0.9900	0.9323	0.9897	0.9299	9.7286	198889.3935	0.9897	0.9302
IIB	6	40	240	37	222	3	18	0.9250	0.9875	0.9273	0.9870	0.9246	8.4232	108080.8972	0.9871	0.9250
IIC	8	37	296	36	288	1	8	0.9730	0.9966	0.9733	0.9966	0.9729	3.8692	684417.6224	0.9966	0.9730
III	7	36	252	36	252	0	0	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
Total	42		1730		1649	14	81	***S**** = 0.7200	***S**** =	0.7284	***S**** =	0.7183			***S**** =	0.7200

Table 11. Survival of Harlequin ducklings from four broods in 1997 and four broods in 1998 in the McLeod River and Whitehorse Creek using Micromort. N = 1,730 duckling days (after Bruner 1997).

Age Class	Daily Survival Rate (s_i) Estimate	Daily Survival Rate (s_i) 95% Confidence Limits	Interval Survival Rate (S_i) Estimate	Interval Survival Rate (S_i) 95% Confidence Limits
IA	97.6	95.7 - 99.5	88.6	80.3 - 97.5
IB	99.4	98.3 - 100	97.7	93.5 - 100
IC	100	100	100	100
IIA	99.0	97.9 - 100	93.2	86.1 - 100
IIB	98.8	97.3 - 100	92.7	85.1 - 100
IIC	99.7	99.0 - 100	97.4	92.3 - 100
III	100	100	100	100
Span Survival Rate Estimate ($\hat{S}^*$)			72.8	61.6 - 86.1

A total of 36 ducklings (18 in 1997 and 18 in 1998) survived to Class III from 50 hatched in the 8 broods with sufficient repeated observations to be included in the calculations. Estimated interval survival rates for these broods for age classes from hatching to fledging ranged from 88% -100% for a span survival rate estimate of 72%. Slightly less than half of the duckling mortality (6 of 14 or 42.9%) occurred in the first interval (Class IA) which represents the first 4 days after hatching. Additional mortality occurred in Class IB (1 out of 14 or 7.1%), Class IIA (3 of 14 or 21.4%), Class IIB (3 of 14 or 21.4%) and Class IIC (1 of 14 or 7.1%). No mortality was observed in Class III ducklings.

4.9 Movement of Broods and Non-nesting Females

As in previous years the primary brood rearing areas are Whitehorse and Drummond Creeks and the McLeod River between Harris Creek and the confluence of Whitehorse Creek. Broods are highly mobile within the system especially after mid-August as is illustrated in the case of Red 9S. Female Red 9S, whose nest location was unknown, was captured along with two of her three Class IIB ducklings on Whitehorse Creek at the mouth of Drummond Creek on August 18 and was observed on the McLeod River near the 2nd trestle below Prospect Creek the next day. These ducklings, not yet able to fly, were taken around the canyon on the McLeod River just above the confluence with Whitehorse Creek.

Female Red 5S (rebanded as Red 7S) nested on Prospect Creek in 1998 and floated eight

Class IA ducklings out of the creek and into the McLeod River on July 5. All subsequent observations of this brood were in the McLeod River upstream of Prospect Creek except for September 3 when they were observed 100 metres downstream of Prospect Creek (Figure 6).

Red 8T (rebanded as Red 7T) nested on Whitehorse Creek and was observed near the first tributary on Drummond Creek with three+ Class IIB ducklings on August 5. She and her ducklings were captured for banding on Whitehorse Creek between Drummond Creek and the campground on August 21 (Figure 7).

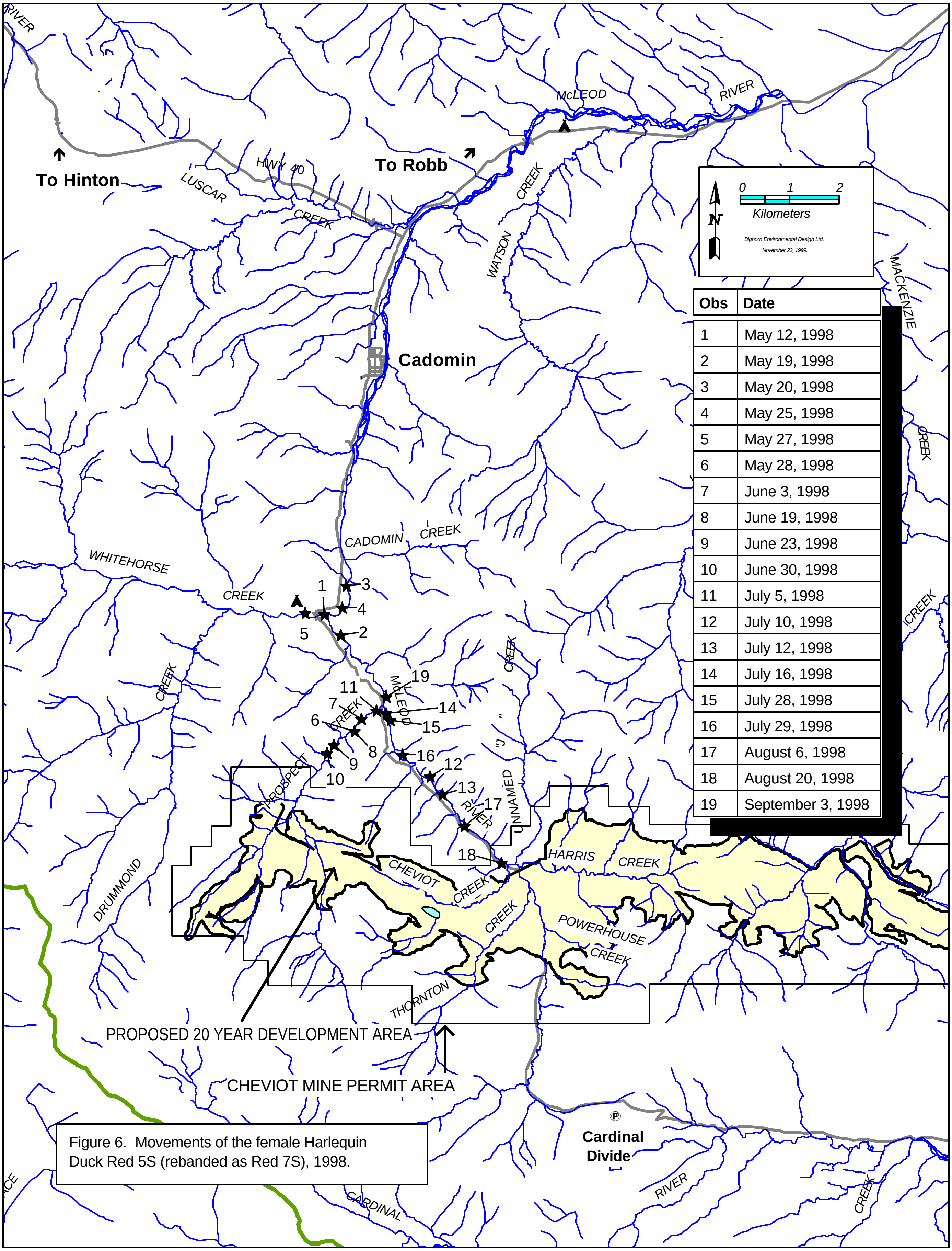
White VP (rebanded as Red 7P) nested on Drummond Creek and was later observed on Whitehorse Creek with four Class IB ducklings (July 13). On August 20 she was captured along with one of her Class IIC ducklings (three escaped capture) on the McLeod River downstream of Cheviot Creek. She was last observed in 1998 on the McLeod River near this same location (Figure 8).

Female Red 5P (rebanded as Red 6Z) was suspected to have nested on Unnamed “J” Creek in 1998 because her radio signal was received from that creek during the nesting period. She was observed upstream of the first trestle upstream of Harris on the McLeod River on July 21 with seven ducklings. This brood used the stretch of the McLeod River between just downstream of Prospect Creek (where they were captured and banded Aug 19) and just upstream of Harris Creek (Figure 9).

The non-nesting females tended to be found in all parts of the system with individual birds using large areas. This mobility is evident in the case of Red 8Z (rebanded as Red 9Z) who was captured on the Luscar Creek beaver ponds downstream of Cadomin on May 20 and whose signal was received above the weir on the McLeod River near the Mountain Park staging area the next day (May 21). On May 25 her signal was received upstream of the Luscar Creek bridge on Luscar Creek. Subsequent observations were on the upper McLeod River between the staging area and just downstream of Prospect Creek (Figure 10).

Red 9A was another example of a non-nesting female who used a large area in 1998. She was captured on the McLeod River near the Highway 40 “T” intersection downstream of Cadomin on May 22. On May 29 her radio signal was received downstream of her capture location on the McLeod River near the Watson Creek campground and on June 12 her signal was received at the confluence of Harlequin and Whitehorse Creeks (Figure 11).

All non-nesting and failed nest females had left the McLeod River/Whitehorse Creek system by August 4, 1998 and the final brood observation was made on September 11 on the upper McLeod River downstream of Cheviot Creek.



Obs	Date
1	May 12, 1998
2	May 19, 1998
3	May 20, 1998
4	May 25, 1998
5	May 27, 1998
6	May 28, 1998
7	June 3, 1998
8	June 19, 1998
9	June 23, 1998
10	June 30, 1998
11	July 5, 1998
12	July 10, 1998
13	July 12, 1998
14	July 16, 1998
15	July 28, 1998
16	July 29, 1998
17	August 6, 1998
18	August 20, 1998
19	September 3, 1998

Figure 6. Movements of the female Harlequin Duck Red 5S (rebanded as Red 7S), 1998.

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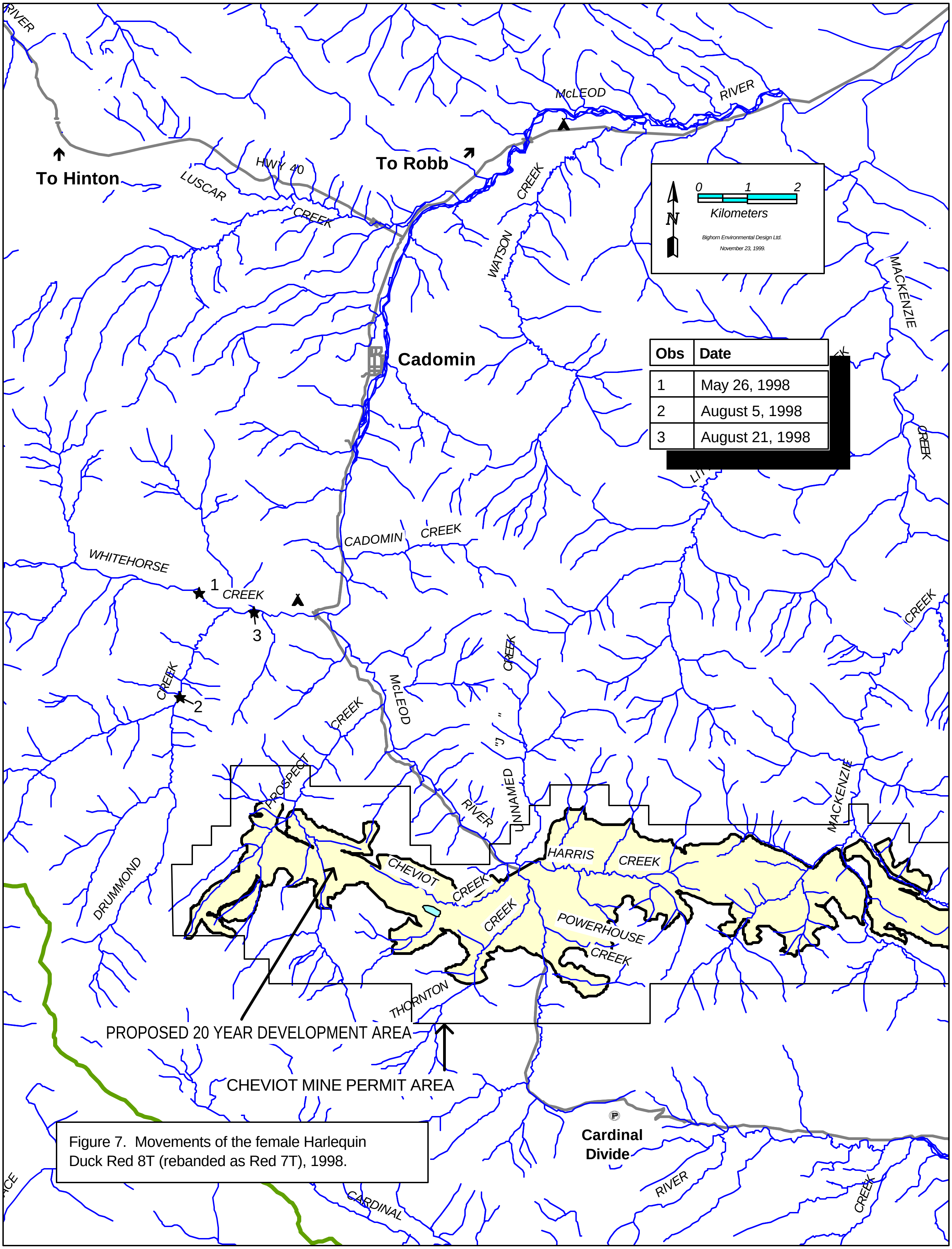

Obs	Date
1	May 26, 1998
2	August 5, 1998
3	August 21, 1998

Figure 7. Movements of the female Harlequin Duck Red 8T (rebanded as Red 7T), 1998.

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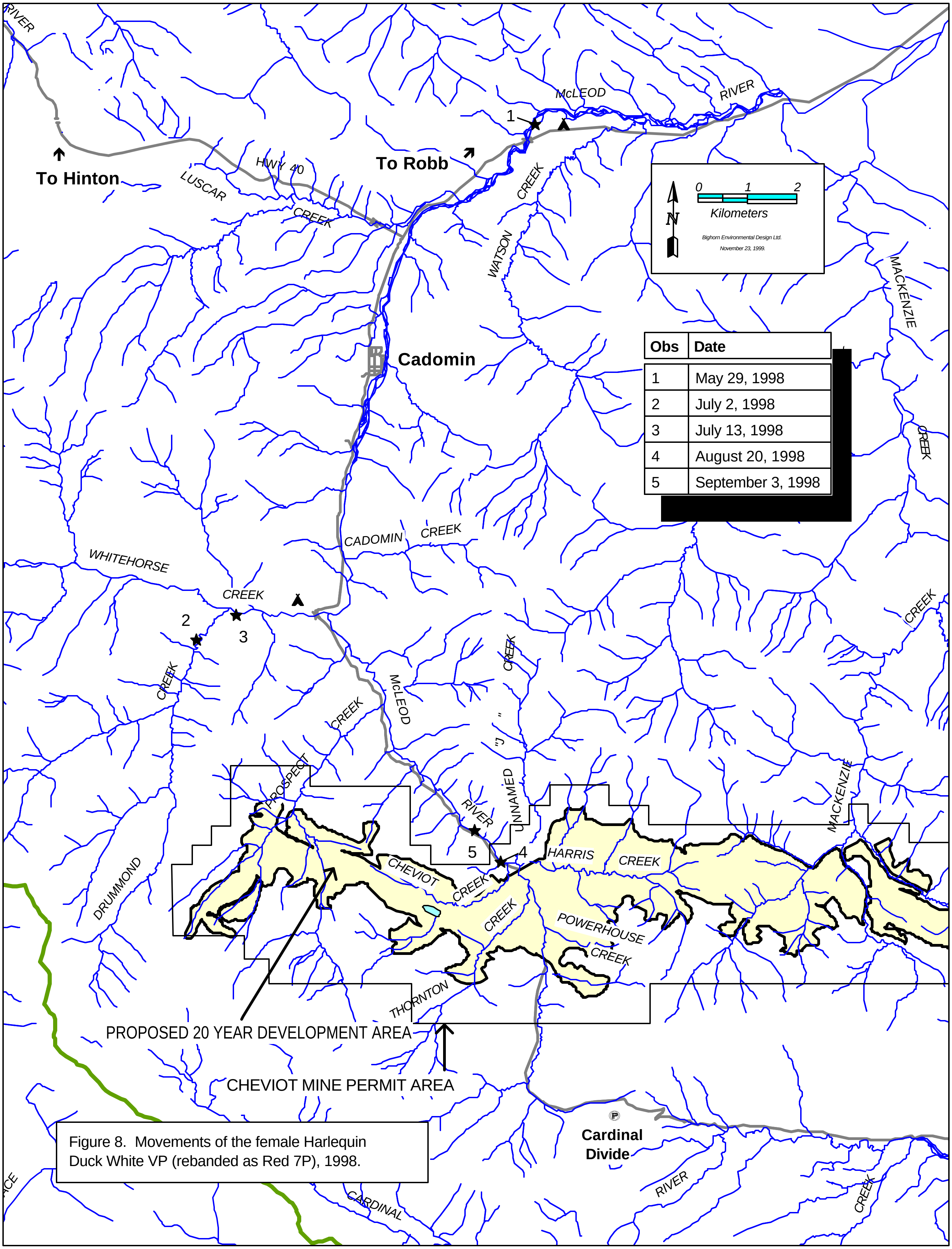

Obs	Date
1	May 29, 1998
2	July 2, 1998
3	July 13, 1998
4	August 20, 1998
5	September 3, 1998

Figure 8. Movements of the female Harlequin Duck White VP (rebanded as Red 7P), 1998.

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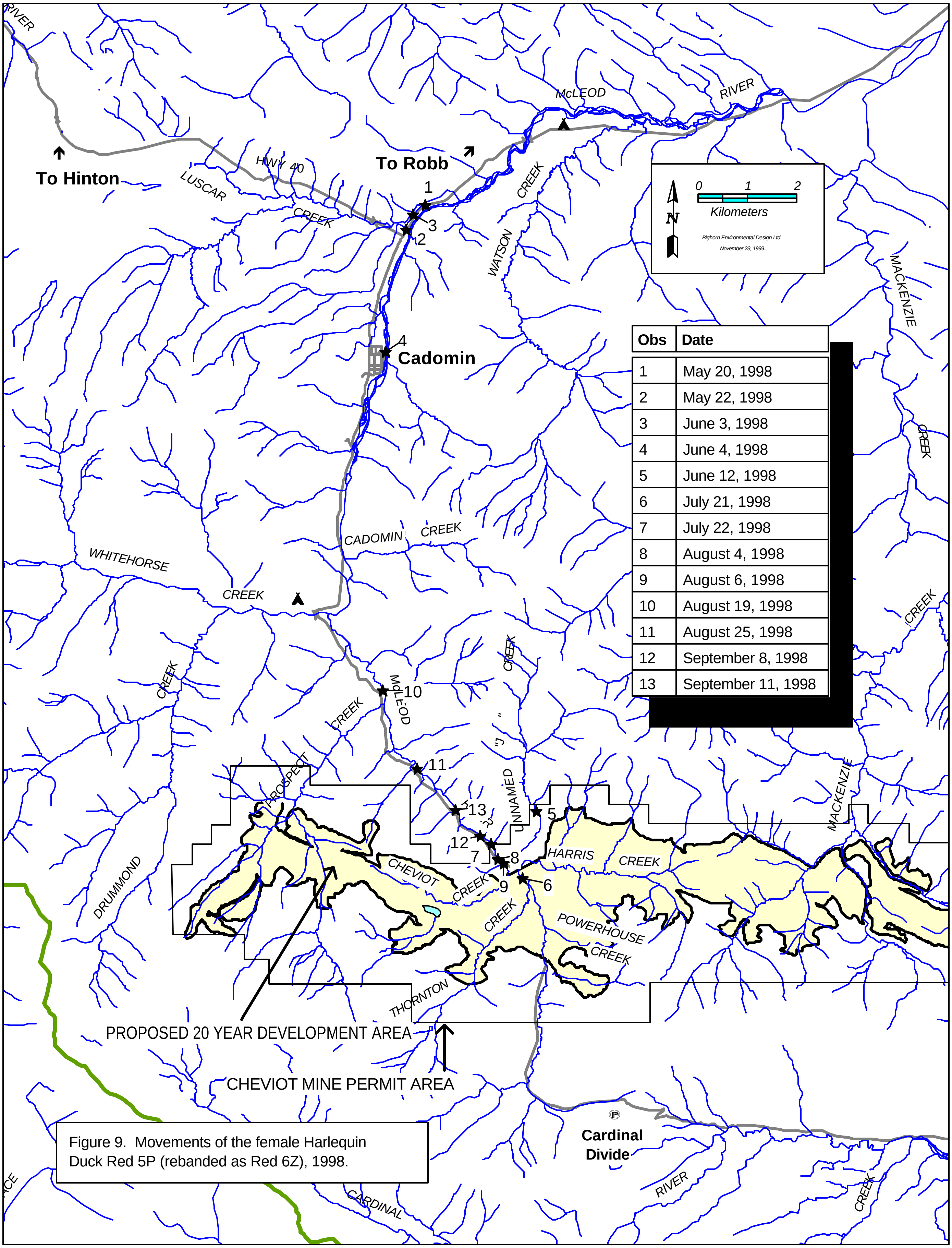

Obs	Date
1	May 20, 1998
2	May 22, 1998
3	June 3, 1998
4	June 4, 1998
5	June 12, 1998
6	July 21, 1998
7	July 22, 1998
8	August 4, 1998
9	August 6, 1998
10	August 19, 1998
11	August 25, 1998
12	September 8, 1998
13	September 11, 1998

Figure 9. Movements of the female Harlequin Duck Red 5P (rebanded as Red 6Z), 1998.

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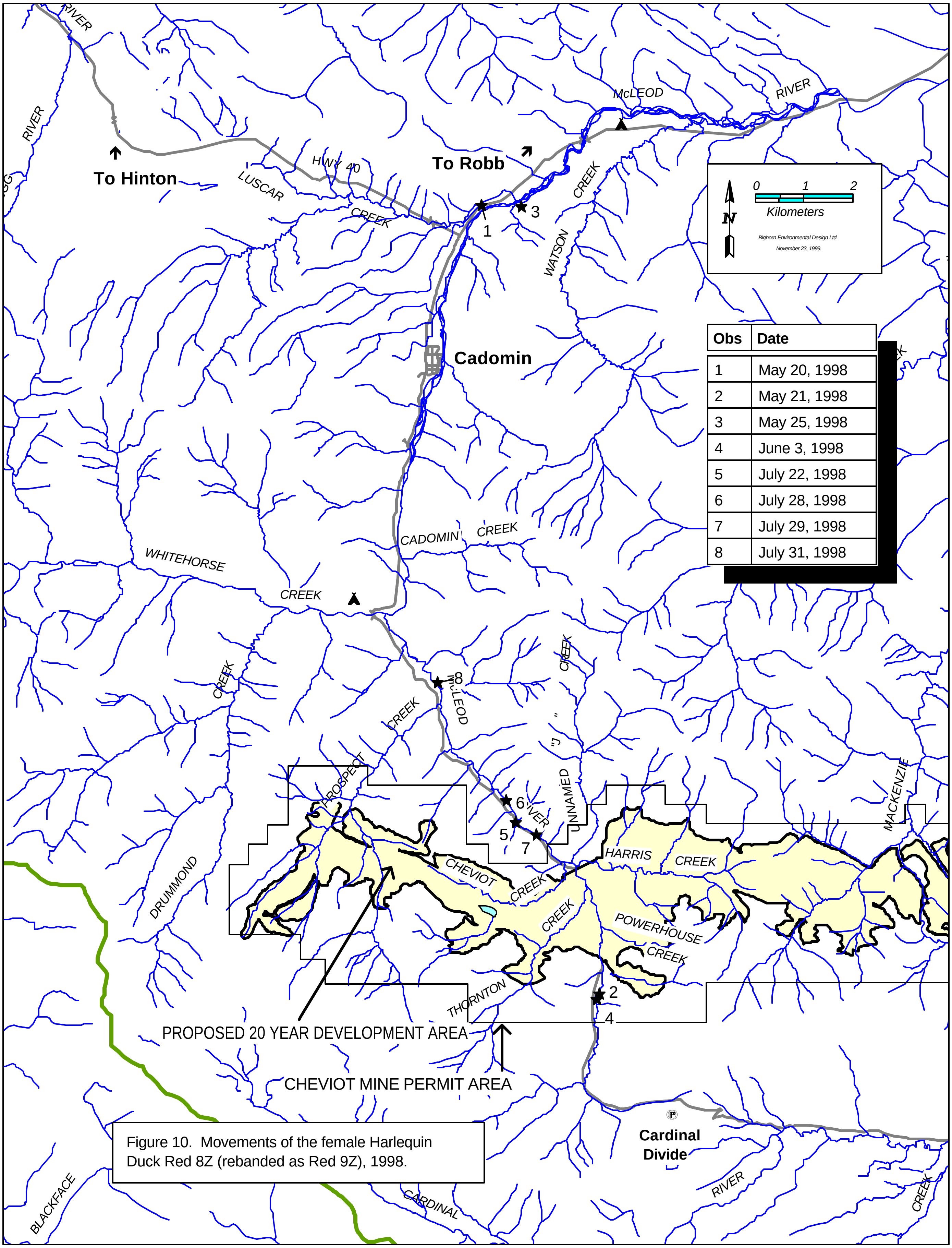

Obs	Date
1	May 20, 1998
2	May 21, 1998
3	May 25, 1998
4	June 3, 1998
5	July 22, 1998
6	July 28, 1998
7	July 29, 1998
8	July 31, 1998

Figure 10. Movements of the female Harlequin Duck Red 8Z (rebanded as Red 9Z), 1998.

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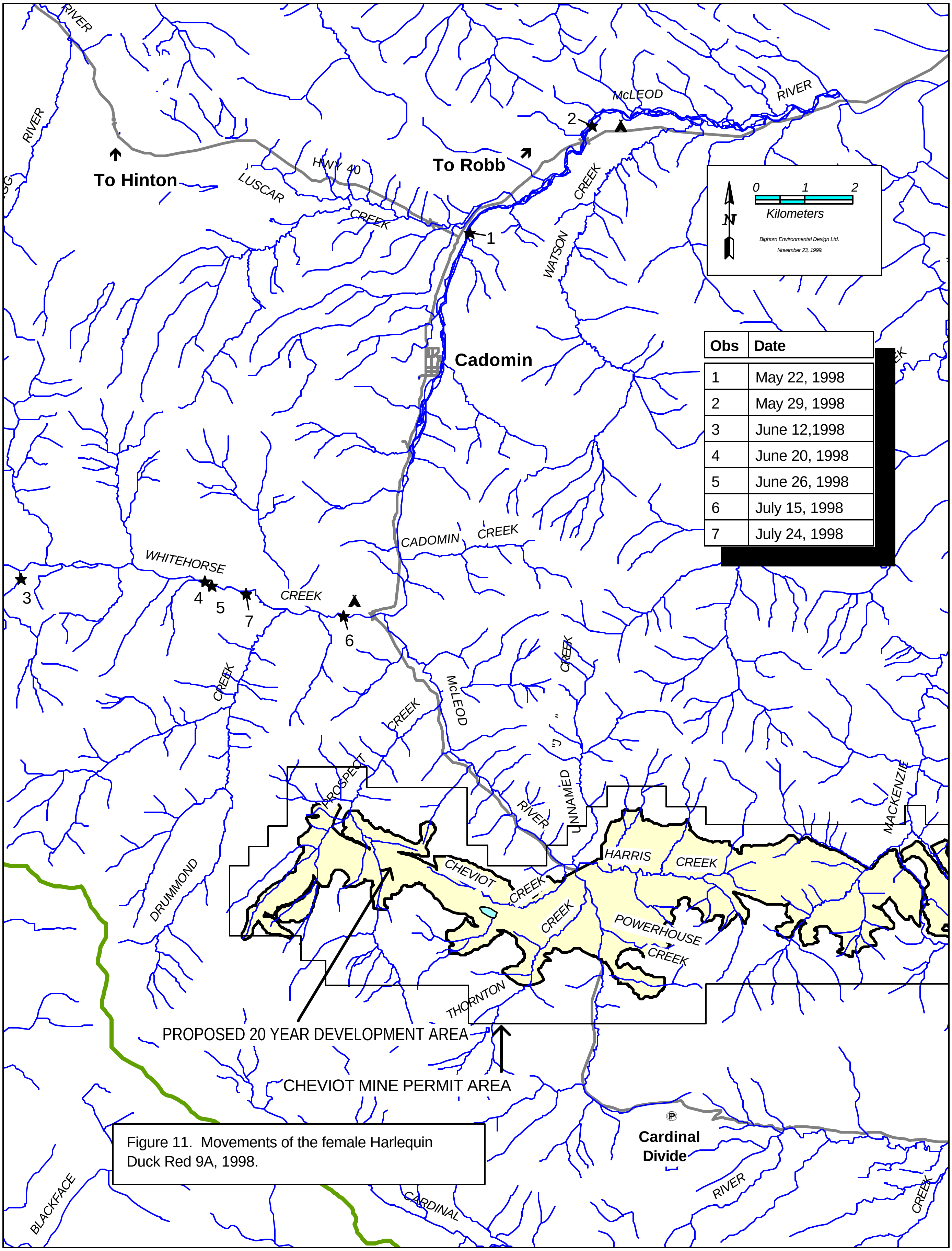

Obs	Date
1	May 22, 1998
2	May 29, 1998
3	June 12,1998
4	June 20, 1998
5	June 26, 1998
6	July 15, 1998
7	July 24, 1998

Figure 11. Movements of the female Harlequin Duck Red 9A, 1998.

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5.0 DISCUSSION

5.1 Harlequin Duck Distribution

During the spring survey, pairs were concentrated on the McLeod River downstream of the confluence of Whitehorse Creek. Twelve pairs were observed in this stretch as opposed to four pair on the McLeod upstream of Whitehorse Creek and one pair on Whitehorse Creek. Eight single males (not identified as part of a male-female pair) were observed with the majority (six) found in the lower McLeod River below Whitehorse Creek. Two single females were observed, one on Whitehorse Creek near the ford and one on Prospect Creek.

The brood survey conducted August 4-6 and 10, identified one brood on the McLeod River below Cadomin, four broods on the McLeod River between Prospect and Harris Creeks; three broods on Drummond Creek, and one brood on Whitehorse Creek between Drummond Creek and the ford.

This change in distribution of Harlequin Ducks in 1998 within the McLeod River/Whitehorse Creek over the course of spring and summer is similar to that documented in 1996 and 1997. Adult ducks congregated in the lower stretches of the McLeod River during the prenesting period in the spring and then dispersed to the upper sections of the McLeod River, Whitehorse Creek and their tributaries at the time of nesting and for brood-rearing. The smaller creeks such as Prospect and Harris are used for nesting purposes however once the ducklings have hatched they are taken out into the McLeod River for rearing. Few observations of broods have been made in these streams during the Cheviot Harlequin Duck study.

Non-nesting females used the same areas at the same time as females with broods which suggests that they are gaining spatial knowledge of breeding streams for future nesting. An example of this behaviour is female Red 2G who was a non-breeder in 1998 and was observed in the upper McLeod River in July and August. She was banded as a duckling on the McLeod River below Prospect Creek in August of 1996 and was observed in Tralee Bay, Hornby Island, BC. in 1997.

5.2 Chronology of Harlequin Ducks in the McLeod River Watershed

Historic and recent observation records of Harlequin Ducks were reviewed to identify arrival and departure dates for males, pairs, non-nesting females as well as estimated incubation and hatching dates (Table 12).

Table 12. Chronology of Harlequin Duck Use in the McLeod River watershed.

Observation	**historic**	**1995**	**1996**	**1997**	**1998**
First Male	May 9 1994 (MB)	May 10	May 22*	May 12	May 5
First Pair	May 9 1994 (MB)	May 10	May 22*	May 12	May 12
Incubation Initiation median and (range)			June 28 (June 13-July 18)	June 13 (June 5-19)	June 15 (June 4-24)
First Brood Observed	July 7 1989 (EJ)	July 20	July 19^	July 9	July 2
Hatch Date median and (range)			July 25 (July 10-Aug. 14)	July 12 (July 4-18)	July 12 (July 1-28)
Last Male	July 4 1979 (KS)	June 30	June 28	June 24	June 22
Last Brood in Downy Stage			August 1	July 24	July 28
Last Non/Failed Nesting Female		July 26	July 31	Aug 14⁺	August 4
Last Harlequin	Sept 21 1994 (MB)	Aug 10"	Sept 16	Sept 10	Sept 11

* = first day of survey for year

⁺ = bird had a dislocated leg and may have been forced to stay longer than normal

" = last day of survey for year; surveys continued in other years beyond the last day Harlequins were observed

^ = systematic surveys were not carried out during the first two weeks of July, 1995 and 1996. Two incidental survey days were carried out July 11 and 15, 1996.

Note: Dates in 1996 and 1997 estimated from age classification scheme from Cassirer and Groves (1996). Dates in 1998 estimated from age classification scheme Wallen (1987). Little difference in median dates were found between the two schemes.

EJ = Edgar Jones, MB = Mark Bugera, KS = Kirby Smith

5.3 Breeding Status of Surveyed Streams

The breeding status of streams in the Cheviot area was identified using the following criteria modified from the Harlequin Duck (*Histronicus histronicus*) habitat conservation assessment and conservation strategy for the U.S. Rocky Mountains (Cassirer et al. 1996):

> **Harlequin Duck Breeding Stream:** A drainage/portion of a drainage used by Harlequin Ducks where breeding is known i.e. a brood or nest has been observed within the past 15 years. Comprised of contiguous stream reaches (and portions of lakes, reservoirs, or bays) used during courtship, nesting and brood-rearing periods not separated by more than 20 km of unoccupied habitat.
>
> **Probable Harlequin Duck Breeding Stream:** A drainage/portion of a drainage used by Harlequin Ducks where breeding is highly suspected i.e. there have been at least 3 independent pair or female observations within the last 15 years. Comprised of contiguous stream reaches (and portions of lakes, reservoirs, or bays) used during courtship, nesting and brood-rearing periods not separated by more than 20 km of unoccupied habitat.
>
> **Breeding Status Unknown:** A drainage/portion of a drainage with at least 1 Harlequin Duck observation but fewer than 3 independent pair or female observations during the breeding season within the last 15 years.
>
> **Breeding Unlikely:** Observations of males during migration (before May 9 and after June 30 in the McLeod watershed). Observations of pairs outside the prenesting season (May 9 - June 30 in the McLeod watershed). Incidental observations in unsuitable habitat such as ponds, or large, low gradient (<1%) rivers, not adjacent to known breeding sites, or observations on streams which have been identified as lacking breeding activity (e.g. migratory staging areas or stopovers).

Historic observations as well as observations from the 1995 - 1998 field seasons were used to assign the breeding status of individual streams (Table 13 and Figure 12).

Harris Creek was previously identified as Probable Breeding in 1996 because of a pair and brood sighting (MacCallum 1997); it was upgraded to Breeding as one nest was located in 1998.

The status of Unnamed "J" Creek was Unknown prior to 1998 when one nest, and a second suspected nest location were identified on this creek in 1998.

No evidence of breeding or brood rearing was found on Thornton Creek in 1998.

A nest was located on Prospect Creek in 1998 which confirms the Harlequin Duck breeding stream status that had been assigned to it in 1996 due to the presence of broods.

Cheviot and Powerhouse Creeks do not possess the correct stream characteristics required by Harlequin Ducks and no observations of Harlequin Ducks have been made on either stream. They are classed as Unlikely Breeding. Cheviot was identified as Probable Breeding in 1996 because of proximity to breeding streams but was since downgraded.

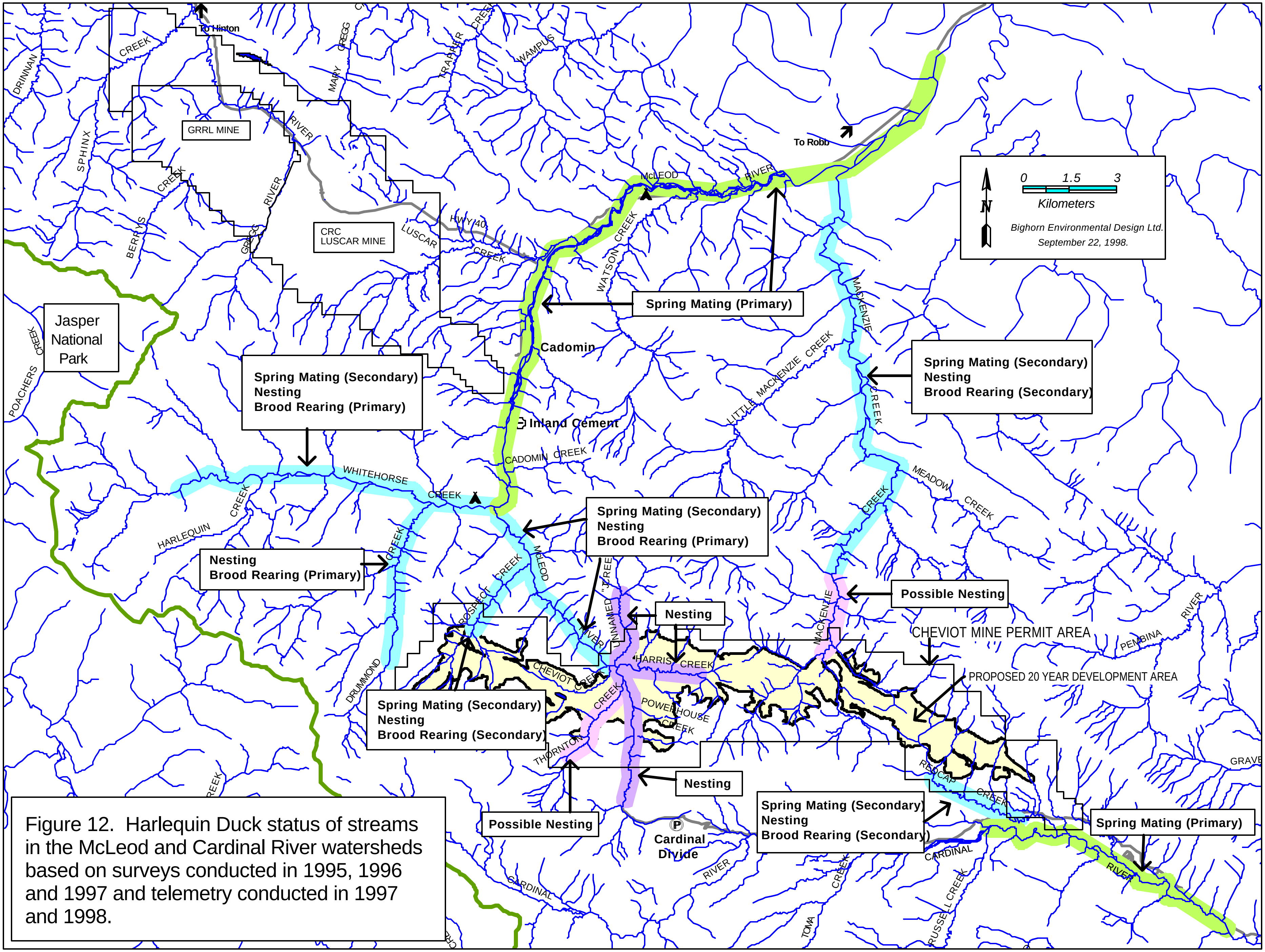

Figure 12. Harlequin Duck status of streams in the McLeod and Cardinal River watersheds based on surveys conducted in 1995, 1996 and 1997 and telemetry conducted in 1997 and 1998.

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Table 13. Harlequin Duck breeding status of creeks and rivers surveyed during the Cheviot Harlequin Duck study, 1995 - 1998 (after Cassirer et al. 1996).

	Confirmed Breeding	Probable Breeding	Status Unknown	Breeding Unlikely
McLeod River	•			
Powerhouse Creek				•*
Thornton Creek		•		
Harris Creek	•			
Unnamed "J"Creek	•			
Cheviot Creek				•*
Prospect Creek	•			
Whitehorse Creek	•			
Drummond Creek	•			
Harlequin Creek			•	
Luscar Creek		•		
Mackenzie Creek	•			
Redcap Creek	•			
Cardinal River		•		
Ruby Creek			•	
Toma Creek				•*

* Unsuitable habitat and no observations during surveys.

5.4 Duckling Survival Rates

Survival rates generated from duckling-days totals are greatly affected by the determination of which age class an observation falls into therefore it is important that the classification by the observer is accurate and that any comparison between populations uses the same or a similar classification scheme. Bruner (1997) used the Cassirer and Groves classification method in his Master's thesis study of Harlequin ducks in the central Cascade Range of Oregon. The Cassirer and Groves method is very similar to the Wallen method used here whereas the Kuchel method has longer periods in the lower age classes (Figure 2) where most of the mortality occurs. The use of Kuchel as a classification scheme could have the effect of increasing the mortality rates in the lower age classes due to the longer time periods. Also, the longer each interval is the more difficult it becomes to accurately determine the daily survival rate.

While the survival rates calculated by Bruner using Micromort were an average of 7% lower than those seen here he also noted the highest mortality rate in the IA age class. The difference in survival rates between the central Cascade Range of Oregon and the McLeod River/Whitehorse Creek could be a result of many factors such as climate and weather, predation, human activity, hen experience and/or year to year variability.

As earlier stated, this study did not include those broods that had less than four separate age class observations. The duckling survival rates as noted above do not take into account the possibility of complete brood mortality that may have occurred in the broods not included in the calculations because of a low number of observations. For example the hen White VP was observed with three Class IC ducklings in 1997 (Table 7) and was not observed again that year. It is not known how many ducklings she had at hatching or how many of the three survived to fledging. This information, if it was available, would affect survival rate calculations.

A consideration not previously discussed and not covered in the literature is the visibility of young broods which are highly secretive and much more difficult to see than older broods. The amount of data available for survival rate calculation is affected by this factor.

Further observational data from subsequent years, if it is available, can be added to that obtained in 1997 and 1998 to provide greater accuracy of survival rates however a comparison of survival rates between years to determine trends will not be valid due to the small annual sample size involved. These factors and considerations tend to limit the validity of year to year comparison to the end numbers of Class III ducklings only.

This section was written to address the question of harlequin duckling hatching-to-fledging survival rates in the McLeod River and Whitehorse Creek area. A measure of productivity, (i.e. the number of young alive at fledging for migration) was obtained. In addition, the age classes of highest duckling mortality were identified providing a basis for the timing of brood surveys.

5.5 Long-term Monitoring Program

A long-term monitoring program will be implemented to document the population response of the Harlequin Duck throughout the life of the Cheviot project. The primary means of monitoring the population will be to:

• conduct a spring survey in a systematic manner to estimate the number of adults (breeding potential)

• conduct a summer brood survey to identify the number of young produced in the system that survive to migrate to their wintering grounds (productivity).

The spring survey will be conducted on the same river stretches of the McLeod River, Whitehorse Creek and their tributaries as surveyed during 1998 (Section 4.2). Incubation initiation can be as early as June 4 in the McLeod River system (Table 12). For this reason it is recommended that the spring survey be carried out during the last week in May to ensure maximum visibility of males and females. The spring survey will be accompanied by a banding program of at least two days prior to the survey. Periodically (every three years) a more comprehensive banding program can be carried out in the spring and summer to maintain a reasonable number of marked birds in the system (30-40).

Parameters generated from the spring survey will include: the number of adults present during prenesting period, sex ratio in the prenesting period, distribution within the system.

A summer brood survey will be conducted early-to-mid August. By this time most broods have developed beyond the Class I (downy) stage and are easier to identify on the water. After mid-August broods become mobile in the system and some leave by the end of August so the possibility of missing broods is increased. Very little mortality of ducklings is be expected after mid-August (Table 11) so numbers generated at this time would be the closest available for an estimate of numbers of young surviving the summer to migrate to their wintering grounds.

August surveys have also been used by Crowley (1994) who conducted brood surveys mid-to-late August in coastal streams and estuaries of Alaska, and by Rodway (1998) who recommended brood counts be conducted in early August in Labrador. The brood survey will be conducted on the same stretches of the McLeod River, Whitehorse Creek and their tributaries as in 1998 (Figure 5).

Parameters generated from the brood survey will include: number of broods produced, ratio of hens with broods to hens present in prenesting, average brood size (calculated early to mid-August; the last date when positive identification of broods in the system can be made), and distribution within the system.

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APPENDIX I CHRONOLOGY OF HARLEQUIN DUCK ACTIVITY IN THE McLEOD RIVER WATERSHED IN 1998

Date	Activity
May 5	Unbanded male observed on McLeod River feeding below Cadomin Creek by road spring.
May 12	First day pairs were observed on McLeod River in 1998: **&** Red 6U & **%** Red 4U and **&** Red 5S (Red 7S) & **%** Red 3C.
May 15, 19-22 26-29, June 5 and 12	Banding on the McLeod River and Whitehorse Creek.
June 22	Last day that a pair (**&** & **%** unknown) were observed in 1998. They were on the McLeod River beaver pond above the random camp.
June 22	Last day a male was observed in 1998.
July 2	The nest of female Red 8T (Red 7T) on Prospect Creek was found to be hatched with eight fresh membranes present.
July 5	First brood of the year. Red 5S (Red 7S) with eight IA ducklings were observed on Prospect Creek. This was similar to 1997 (July 9) but earlier than1996 (July 19) and 1995 (July 20).
July13	Female White VP (Red 7P) and four ducklings were observed on Whitehorse Creek below Drummond Creek.
July 28	Last brood observed in downy stage. Unbanded female with two Class IC ducklings. Red 5S (Red 7S) nearby.
July 29	Banding of staging females, McLeod River
July 31	Female Red 8Z (Red 9Z) observed 2:10 p.m. on McLeod River
August 2	Female Red 8Z (Red 9Z) observed 8:00 a.m. on White Rock's Boundary Bay, BC.
August 4	Last day nonbreeding/failed breeding females were observed in the McLeod watershed: Red 9P, Red 3L, Red 2G and one unbanded female.
August 18-21, 27	Banding of broods on the McLeod River and Whitehorse Creeks.
August 20	Captured female White VP (Red 7P) and one of her four Class IIC ducklings (three escaped), McLeod River below Cheviot Creek.
August 20	First fully feathered brood observed. Female Red 5S (Red 7S) with five Class III ducklings on McLeod River below Harris Creek.
September 11	Last day that Harlequin Ducks were observed in the McLeod River watershed despite surveys on September 16 and 17.