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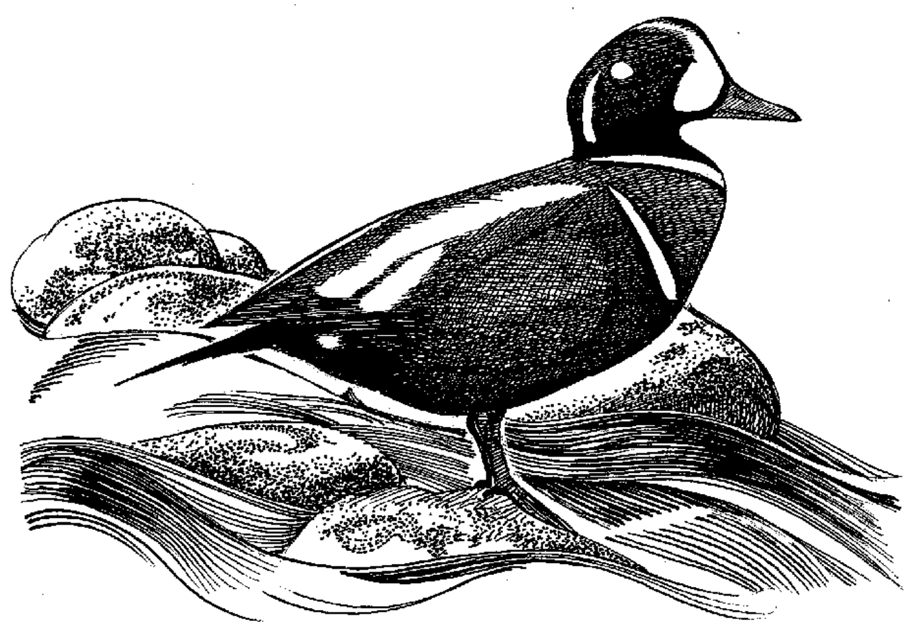
RESOURCE STATUS AND ASSESSMENT BRANCH

Proposed Monitoring Plan for Harlequin Ducks in the Bow Region of Alberta

Cyndi M. Smith



Alberta Species at Risk Report No. 16

Alberta
SUSTAINABLE RESOURCE DEVELOPMENT

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DISCLAIMER

The views and opinions expressed are those of the author and do not necessarily represent the policies or positions of the Department or the Alberta Government.

EXECUTIVE SUMMARY

In Alberta harlequin ducks nest in relatively low densities throughout the Rocky Mountains and the foothills of the Eastern Slopes. In 1996 they were listed as a sensitive species (Yellow A list) in Alberta. Harlequin ducks are an integral part of aquatic ecosystems along Alberta's Eastern Slopes and the adoption of a long-term monitoring plan for harlequin ducks will ensure that this population is maintained in a sustainable healthy state.

This monitoring plan was designed to address three objectives. First, to make a preliminary assessment of the status of all potential harlequin duck breeding streams in the Bow Region of Kananaskis Country, and describe methods to continue this assessment with field work over a number of years. Second, to describe and assess the methods used to determine the population status of the ducks on the Elbow and Kananaskis rivers; to asses the effectiveness of helicopter surveys used in central Alberta; and to recommend which methods to use to continue to estimate population size. Third, to describe and assess methods used to determine productivity of harlequin ducks on the Elbow and Kananaskis rivers, and their validity for other streams.

Thirty-five streams in the Bow Region of Kananaskis Country were assessed for use by harlequin ducks. Breeding has been confirmed on nine of these creeks and rivers. Twelve waterbodies were classified as potential due to the fact that no surveys have been conducted in those areas, and no random observations have been collected. Aerial surveys are recommended for determining presence or absence of harlequin ducks on streams in the spring, with the goal of determining breeding status on the "unknown" and "potential" breeding streams. Surveys should be conducted between May 15 and May 30. A timetable for monitoring the known breeding streams over five-to-ten-year periods should be established, to track if any streams lose their populations.

To serve as a benchmark area population counts and productivity estimates should be continued on the relatively undisturbed Kananaskis River. Aerial surveys are recommended to compare counts over a number of years to detect trends (if they are present). Brood surveys could be conducted from the air also, but further comparisons need to be conducted between ground and aerial survey detection of females with young, to determine if this is a suitable methodology.

The estimated reproductive output (R_0) for the Elbow River declined from 6.24 to 1.18 between 1996 and 2000, while the estimated R_0 for the Kananaskis River remained high at 3.90, 4.93 and 3.96 for 1998-2000. If the reproductive output on the Elbow River continues to be less than 2.0, the population could be declining and this trend would be of concern. Population counts and productivity estimates could be continued on the Elbow River, to determine if the declining productivity is part of natural variation or if there may be human-caused stresses on the population.

Population counts and productivity surveys could be undertaken for a stream that is subject to resource extraction that could affect water quality, the invertebrate food source, or riparian habitat, as a comparison against the benchmark area. Cataract Creek would be a good candidate since it is a known breeding stream, and concerns have been expressed over the impact of logging activities in the upper watershed on water clarity and aquatic invertebrates.

1.0 BACKGROUND

Harlequin ducks (Histrionicus histrionicus) are small sea ducks (tribe Mergini) that spend eight to ten months of the year living at coastal areas and migrate inland during the summer to nest along mountain streams (the only duck in North America to do so). Within North America the species can be found along both the Atlantic and Pacific coasts. In 1990 the harlequin duck was listed as "endangered" in eastern Canada, becoming the first North American duck to reach such critical status in modern times (Goudie 1991). The Pacific population, historically larger than the Atlantic population, is also showing signs of decline (Robertson and Goudie 2000).

In Alberta these ducks nest in relatively low densities throughout the Rocky Mountains and the foothills of the Eastern Slopes, where they are breeding at the periphery of their range. In 1996 harlequin ducks were added to the Yellow “A” list of endangered and threatened species in Alberta (Anon. 1996): “sensitive species that are not currently believed to be at risk, but may require special management to address concerns related to naturally low populations, limited provincial distributions, or demographic/life history features that make them vulnerable to human-related [emphasis theirs] changes to the environment.” The welfare of the harlequin duck appears to be intimately related to the availability of fast-flowing, non-polluted water, and an area of river where it can breed and nest away from human disturbance. It has been suggested that the harlequin duck's dependency on undisturbed mature and old growth habitat, and streams with healthy macroinvertebrate populations make it a good indicator of healthy aquatic ecosystems (Bengston and Ulfstrand 1972, Clarkson 1994).

Six years of intensive research on the Elbow River (1995-2000), and three years on the Kananaskis River (1998-2000), provides a good baseline of data and a valid starting point from which to monitor the status of the harlequin duck population in those two watersheds. Based on our current level of knowledge, the Kananaskis and Elbow rivers are considered to be provincially important breeding streams for harlequin ducks in Alberta (P. Gregoire, pers. comm., Kneteman & Hubbs 2000). No other concentrations have been reported in southern Alberta. The median population estimate for the Elbow River for 1996-2000 was 27.0 ± 4.2 (S.D.) adult harlequin ducks. The estimate for the Kananaskis River was 41.0 ± 8.3, 43.0 ± 9.8 and 71.0 ± 19.3 for 1998, 1999 and 2000, respectively. These estimates are surpassed by 68 ± 2 (S.D.) for the McLeod River/Whitehorse Creek system in 1999 (MacCallum and Godsalve 2000) and the Bow River in Banff National Park, at 153 ± 25 for 1995-1999 (Smith 2000b). A status report for the province is expected in 2001.

Data obtained on parameters such as survival rate and productivity from these two streams is considered to be representative of ducks on other streams, although Kneteman and Hubbs (2000) suggest the possibility that changes in population size (and by inference other parameters) might be evident first in small tributaries of lower quality habitat rather than in the larger higher quality rivers. But the smaller numbers of birds found in the smaller tributaries would make it very difficult to obtain some of the same data as in the larger rivers.

2.0 INTRODUCTION TO MONITORING

For many years monitoring the health of a wildlife population has involved counting individuals to determine its size, density, and trend over time. However, it is increasingly being recognized that monitoring only these parameters is insufficient for conservation purposes (Goss-Custard 1993). Densities alone may be misleading indicators as they are not necessarily related to habitat quality in a linear manner (Crick et al. 1997). Additionally, for a long-lived species such as the harlequin duck, declines in population size might only be observed after long periods of low survival or reproduction (Crick et al. 1997). Thus, we need to have an understanding of the demographic processes that lead to population changes: reproduction, survival, emigration and immigration (Greenwood et al. 1993). We also need to understand other life history factors, such as the food resources required.

It is important to keep the following distinctions in mind (Baillie 1990):
- surveys are studies of numbers and distributions of birds at particular points in time,
- surveillance is the measurement of changes in population variables with time, and
- monitoring is comparing observed changes with a standard measurement.

Monitoring implies a pre-defined threshold, which if exceeded or not reached, will be used to trigger management action. Thresholds for animal populations are difficult to establish, as we usually don't have enough long-term data to understand normal patterns of population variability (Baillie 1990). The length of the time series and the validity of the starting point (Thomas 1996) affect the accuracy of all trends. Accurate data obtained from a long-term monitoring program will allow managers to make informed decisions regarding harlequin duck populations in the Bow Region.

3.0 OBJECTIVES

There are three objectives for this monitoring plan:

a) Make a preliminary assessment of the status of all potential harlequin duck breeding streams in the Bow Region of Kananaskis Country, and describe methods to confirm stream breeding status.
b) To describe and assess methods used to determine the status of two specific harlequin duck populations (on the Elbow and Kananaskis rivers); to assess the effectiveness of helicopter surveys used in central Alberta; and to recommend which methods to use to continue to estimate population size on these streams and others.
c) To describe and assess methods used to determine productivity of harlequin ducks on the Elbow and Kananaskis rivers, and their validity for other streams.

4.0 ASSESSING AND SURVEYING STREAMS FOR BREEDING STATUS

Not all streams used by harlequin ducks during the breeding season are used for nesting or brood rearing; some streams may be used only during migration to and from breeding areas.

4.1 Assessing Streams

In order to assess waterbodies in Kananaskis Country, with respect to potential use by harlequin ducks, this study used categories identified in Cassirer et al. (1996) and utilized by MacCallum and Godsalve (2000) and Smith (2000b):

breeding stream — drainage or portions of drainages where breeding is known (i.e., a brood or nest has been observed in the last 15 years); comprised of contiguous stream reaches (and portions of lakes, reservoirs or bays) used during the courtship, nesting and brood rearing periods not separated by more than 20 km of unoccupied habitat

probable breeding stream — drainage or portions of drainages where breeding is highly suspected (i.e., there have been at least three independent pair or female observations within the last 15 years); comprised of continuous stream reaches (and portions of lakes, reservoirs or bays) used during the courtship, nesting and brood rearing periods not separated by more than 20 km of unoccupied habitat

unknown breeding status — drainages or portions of drainages with one or two independent observations of pairs or females within the last 15 years

breeding unlikely — observations of males during migration periods; observations of pairs outside the pre-nesting season; or, incidental observations in unsuitable habitat (e.g., ponds), not adjacent to known breeding sites; no observations to date

potential breeding stream — drainage or portions of drainages where no observations have been recorded and no surveys done, but that have suitable habitat

The 15-year time period is used because harlequin ducks are a long-lived species, do not breed until they are three-to-five years of age, may not breed every year, and have low productivity. As a result it may take a number of years to determine the breeding status of a stream. Streams that are currently categorized as having “probable”, “unknown”, “unlikely” or “potential” status may perhaps be upgraded as more observations are obtained; or downgraded if the 15-year time frame is reached with no further observations.

Using historical records (Smith 1996) and observations obtained since 1995 (Smith 1997, 1998, 1999, 2000a), thirty-five streams in the Bow Region of Kananaskis Country were assessed for use by harlequin ducks (Table 1). Breeding has been confirmed on nine of these creeks and rivers. While pairs have been observed on lakes in the area, no nests have been found on lakes. It is most likely that females nested on streams or rivers associated with those lakes. Twelve are classified as "potential breeding streams" for the reason that no surveys have been conducted in those areas, and no random observations have been collected.

Table 1. Classification of waterbodies in Alberta Environment's Bow Region regarding breeding use by harlequin ducks.

Waterbody	Known[a]	Probable[b]	Unknown[c]	Unlikely[d]	Potential[e]
Baril Ck.					√
Barrier Lake				√	
Burnt Timber Ck.					√
Cataract Ck.	√				
Dyson Ck.			√		
Elbow R.	√				
Etherington Ck.			√		
Evan Thomas Ck.					√
Fallentimber Ck.					√
Ford Ck.			√		
Ghost R.					√
Highwood R.	√				
Jumping Pound Ck.			√		
Junction Ck.			√		
Kananaskis R. – lower	√				
Kananaskis R. – upper	√				
Little Elbow R.					√
Lower Kananaskis L.				√	
North Burnt Timber Ck.					√
Pocaterra Ck.			√		
Prairie Ck.			√		
Quirk Ck.			√		
Ranger Ck.			√		
Ribbon Ck.	√				
Sheep R.	√				
Sibbald Ck.			√		
Smith-Dorrien Ck.	√				
Smuts Ck.					√
South Ghost R.					√
Storm Ck.	√				
Threepoint Ck.					√
Trap Ck.					√
Upper Kananaskis L.				√	
Waiparous Ck.					√
Ware Ck.			√		

[a] nest or brood seen in last 15 years
[b] at least three independent pair or female observations in last 15 years
[c] one or two independent pair or female observations in last 15 years
[d] observations of males during migrations, pairs outside of pre-nesting season, or in unsuitable habitat
[e] no observations on record, but habitat may be suitable

4.2 Surveying Streams

It is recommended that streams classified as "unknown" (11 of 35) should be surveyed within the next five years to determine breeding status. The second priority would be streams that are currently classified as "potential" (n = 12). Once the status has been determined for these streams, then a timetable for monitoring the known breeding streams over five-to-ten-year periods should be established.

Stream surveys for presence/absence of harlequin ducks to determine breeding status could be conducted on foot, by boat, or by helicopter. Boat surveys are not recommended as birds are frequently "chased" downstream ahead of the boat, causing stress to the birds while making it difficult to obtain an accurate count. Also, birds may go unobserved when paddlers are busy negotiating rough water. Ground surveys may be more accurate and less expensive than aerial surveys, but more time and labour intensive. Aerial surveys may be particularly feasible for remote areas. Identification of which stream reaches need to be surveyed should be done utilizing topographical maps, aerial photographs and local knowledge.

Regardless of the method chosen, surveys should be conducted between May 15 and May 30. The median date of observation of first pairs was May 9 (range: May 1-25) on the Elbow and Kananaskis rivers, between 1993 and 1999 (Smith 2000a). If surveys are conducted much later, then females may be missed if they have started nesting.

4.2.1 Ground Surveys

Ground-based stream surveys should be conducted by hiking along/in the streams, preferably moving upstream. Ducks, if disturbed, often float downstream and therefore will not be re-counted. Surveyors should walk carefully and quietly, constantly using binoculars to scan the stream, particularly eddies behind rocks, and shoreline loafing sites. On small streams surveyors may have to move away from the stream to get beyond the birds before resuming the survey, so that they are not "pushed" upstream and recounted. Data recorded includes area surveyed (start and end locations), time spent, birds observed (males, females, pairs) and their locations, as well as habitat characteristics.

As many of the streams are in remote areas and in bear country, it is recommended that two surveyors work as a team. Where there is road access, two vehicles will be required – one for the start point and one for the end point. In less accessible areas helicopter assistance may be required. If the stream will require more than one full day to complete the survey, then two or more teams should be deployed on different sections, so that the stream is surveyed in one day.

4.2.2 Aerial Surveys

Aerial surveys for harlequin ducks have not been conducted in Kananaskis Country, but have been conducted from 1998-2000 in the McLeod and Cardinal river watersheds, and in 10 watersheds in Willmore Wilderness Park (Gregoire et. al. 1999, Kneteman and Hubbs 2000). These studies determined that aerial surveys are an effective method of censusing harlequin ducks, particularly in remote areas. The stream must have a wide enough channel for the helicopter to fly below tree height, or a narrow channel that is not treed to the water's edge, and flat lighting conditions (bright sunlight makes it difficult to distinguish the ducks from the background). In comparative surveys on the McLeod River aerial surveys counted approximately 70% of the birds that were counted during ground surveys.

Kneteman and Hubbs (2000) recommend the use of a Bell 206B Jet Ranger helicopter, flown approximately 30 m above the water at an average speed of 55 km/hr. Streams should be flown in an upstream direction (although they occasionally flew downstream to minimize flying hours). Streams were flown until the headwaters were reached or vegetation and channel constriction markedly obscured visibility. The left front passenger was responsible for navigating and observing, while the rear right passenger observed and recorded data onto field data sheets. GPS locations were recorded for start and end points of the survey, and for all duck observations. The number of ducks and group composition (pairs, single male or female) were recorded. Spring surveys were conducted in late May – early June, between 10:00 – 16:00 (the time when viewing conditions were considered to be most favourable).

Aerial surveys are recommended for determining presence or absence of harlequin ducks on streams in the spring, with the goal of determining breeding status of these streams. A discussion on using aerial surveys to estimate population size will be found in section 5.3.

5.0 ESTIMATING POPULATION SIZE

There are two general methods for estimating population size. One is to attempt to census the entire population. However, it is difficult to count all birds since a bird's detectability depends on many factors, such as weather, observer, and bird density. The second general method is to base the estimate upon surveys of a marked sample of the population (Thomas 1996). Inherent to any method of estimating population size is variation in the numbers of animals counted. This section will first describe how a power analysis can be used to assess the ability to detect change, then describe both general methods and suggest changes to both based on a power analysis. It will then be up to managers to decide which method(s) will be used based on level of precision sought, funding and labour availability considerations.

5.1 Power Analysis and Detection of Trends

The variation in the numbers of animals counted may be natural (e.g., births, deaths, weather effects) or due to the flaws of the chosen monitoring technique (e.g., observer differences, different fractions of individuals being counted each time, survey length, number of plots). This variation in numbers partially obscures the presence of any long-term trends. The probability that a monitoring program will detect a trend in sample counts when the trend is real, despite the variations in the count data, represents its statistical "power". The consequences of ignoring statistical power include collection of count data that is insufficient to make reliable inferences about population trends, or conversely, the collection of data in excess of what is needed (Gibbs 1995). Small sample sizes, with high variability, will reduce our ability to detect change (power).

Statistically speaking, power is defined as $1 - \beta$ (beta), where β is the probability of wrongly accepting the null hypothesis when it is actually false, known as a Type II error. Power is essentially the likelihood of correctly rejecting the null hypothesis. When the objective is to monitor a population trend from an index of population abundance over time (as in Table 2), then we must test the null hypothesis that there has not been a change in population index between two time points (in this case, years) against the alternative that the population has changed. If a significant change in population size has occurred, we want to know what the probability is that it has been detected from our surveys. The conclusion that a significant change in population has occurred, when in fact it has not, is termed a Type I error, while the conclusion that no change has occurred, when in fact it has, is a Type II error. As a probability, power is expressed as a number between 0 (low power) and 1 (high power), although sometimes it is expressed as a percentage.

Table 2. Power analyses of roadside surveys for estimating harlequin duck population size on the Elbow River, Alberta.

Trend (%)	A	B	C	D	E	F	G	H	I	J	K
mean N	26.24	26.24	26.24	26.24	26.24	26.24	26.24	26.24	26.24	26.24	26.24
S.D.	6.12	6.12	6.12	3.06	3.06	3.06	3.06	3.06	2.00	2.00	2.00
surveys/yr	5	6	7	5	3	2	3	5	5	5	2
years	5	5	5	5	5	5	6*	3	5	3	4
-10	0.64	0.75	0.80	1.00	0.94	0.79	0.81	0.64	1.00	0.92	0.84
-9	0.60	0.68	0.72	0.99	0.91	0.69	0.77	0.53	1.00	0.87	0.79
-8	0.49	0.59	0.66	0.97	0.84	0.64	0.67	0.43	1.00	0.79	0.67
-7	0.42	0.49	0.53	0.94	0.75	0.55	0.60	0.37	1.00	0.68	0.60
-6	0.33	0.42	0.46	0.88	0.66	0.46	0.48	0.27	1.00	0.58	0.48
-5	0.24	0.29	0.35	0.73	0.50	0.35	0.40	0.23	0.98	0.46	0.37
-4	0.18	0.21	0.23	0.56	0.38	0.25	0.28	0.18	0.91	0.32	0.25
-3	0.12	0.15	0.17	0.39	0.22	0.14	0.17	0.12	0.72	0.21	0.17
-2	0.07	0.09	0.10	0.19	0.14	0.11	0.10	0.07	0.41	0.13	0.10
-1	0.06	0.07	0.07	0.08	0.07	0.05	0.06	0.06	0.15	0.08	0.05
0	0.04	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05
+1	0.05	0.07	0.08	0.09	0.08	0.07	0.06	0.06	0.15	0.07	0.06
+2	0.08	0.09	0.10	0.23	0.14	0.10	0.11	0.07	0.45	0.12	0.11
+3	0.16	0.16	0.19	0.45	0.3	0.19	0.21	0.12	0.79	0.21	0.21
+4	0.26	0.29	0.34	0.70	0.49	0.30	0.34	0.17	0.96	0.36	0.31
+5	0.36	0.41	0.49	0.90	0.65	0.46	0.52	0.27	1.00	0.51	0.47
+6	0.50	0.56	0.61	0.97	0.84	0.65	0.69	0.38	1.00	0.69	0.63
+7	0.66	0.72	0.82	1.00	0.94	0.77	0.83	0.47	1.00	0.82	0.79
+8	0.78	0.87	0.89	1.00	0.98	0.87	0.92	0.60	1.00	0.93	0.85
+9	0.89	0.93	0.96	1.00	1.00	0.94	0.97	0.71	1.00	0.97	0.94
+10	0.94	0.98	0.99	1.00	1.00	0.98	0.99	0.80	1.00	0.98	0.98

* surveys conducted every other year

Column A is the baseline analysis, using values derived from surveys conducted from 1995 to 2000 (Smith 2001). These values are mean population estimate (N), S.D., number of surveys per year, and number of years it will take the trend to be detected. Columns B-K are the results produced by varying the initial values. Power estimates in bold face indicate the first estimate equal to or greater than 0.80 (0.79 is considered to be rounded up to 0.80) for that particular decreasing or increasing trend in N. See text for full discussion of results.

Three of the survey parameters can be manipulated when analyzing power to detect trends. One way is to increase the number of years over which you wish to detect a trend. Secondly, the number of surveys that are conducted each year can be increased. A third way is to reduce the variances (S.D.). Smaller variances relative to initial counts increase power to detect trends.

There are many software programs available to help in power analysis. MONITOR (Gibbs 1995) is a free program available from the United States Geological Survey web site at <http://www.pwrc.usgs.gov/powcase/index.html>. The power estimate generated by MONITOR indicates how effective a monitoring program is at detecting trends that might occur in the population being monitored. A monitoring program whose power estimates exceed 0.80 would detect trends, should they occur, more than 80% of the time (Cohen 1977), at a significance level of 0.05.

Goudie et al. (1994) suggested that a decrease in the adult harlequin duck population of 2-3% per year is enough to cause the population to decline. Obtaining high power values for trends of lower magnitude (1%, 2% and 3%) is often difficult however, particularly for decreasing trends. It would be realistic to be able to detect a decrease of 10% in the numbers of harlequin ducks.

5.2 Analysis of Using Marked Samples to Obtain Population Estimates

A complete description of methods for capturing and marking harlequin ducks can be found in Smith (2000a). All capturing and marking must be done under an Environment Canada Banding Permit, as well as Alberta Research and Collection permits. Roadside surveys for censusing harlequin ducks and re-sighting marked birds were established along the Elbow River and the Kananaskis River (Smith 2000a). The emphasis was on establishing a repeatable survey that is relatively easy to complete. The purposes of the surveys were to obtain numbers of banded and unbanded birds for a population estimate, and to read the codes of banded birds to calculate a survival estimate (see Section 6). A Capture-Mark-Recapture/Resighting (CMR) methodology was used to calculate population estimates from marked birds observed on the roadside surveys (Smith 2000a).

Table 2 is a power analysis of roadside surveys for estimating harlequin duck population size on the Elbow River. Column C show that at the current variance (S.D.) it would require seven surveys per year for five years (35 surveys in total) to detect a 10% declining trend. If the variance could be halved (column F), then it would take only two surveys per year (10 surveys). Or, if three surveys were conducted every other year (column G), a 10% declining trend could be detected in six years (nine surveys). If the variance could be lowered to 2.00, then it would require either five annual surveys for three years (15 surveys), or two annual surveys for four years (eight surveys) to detect the same trend. Note that an increasing trend would be picked up using fewer surveys.

A power analysis of roadside surveys for estimating harlequin duck population size on the Kananaskis River shows that it would require six surveys every year for five years (30 surveys) to detect a 10% declining trend (column C, Table 3), but if the variance could be dropped to 5.00 then three surveys could be conducted every other year over six years (nine surveys) to detect the same trend (column E). Columns G, H and I show the options if the variance could be lowered to 2.00.

Table 3. Power analyses of roadside surveys for estimating harlequin duck population size on the Kananaskis River, Alberta.

Trend (%)	A	B	C	D	E	F	G	H	I
mean N	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00
S.D.	9.05	9.05	9.05	5.00	5.00	2.00	2.00	2.00	2.00
surveys/yr	5	22	6	7	3	2	1	2	2
years	3	3	5	3	6*	3	5	3	6*
-10	0.24	0.79	0.81	0.79	0.83	0.81	0.94	0.81	1.00
-9	0.20	0.73	0.75	0.69	0.76	0.72	0.89	0.74	1.00
-8	0.18	0.62	0.66	0.62	0.65	0.67	0.84	0.63	0.98
-7	0.16	0.53	0.56	0.49	0.57	0.53	0.79	0.56	0.96
-6	0.11	0.40	0.45	0.40	0.47	0.43	0.64	0.46	0.91
-5	0.09	0.29	0.35	0.28	0.36	0.33	0.52	0.33	0.82
-4	0.07	0.21	0.25	0.20	0.23	0.26	0.37	0.25	0.64
-3	0.08	0.15	0.17	0.14	0.17	0.14	0.26	0.15	0.45
-2	0.06	0.09	0.13	0.08	0.11	0.08	0.14	0.11	0.23
-1	0.04	0.07	0.06	0.07	0.06	0.07	0.08	0.07	0.10
0	0.04	0.06	0.06	0.05	0.05	0.06	0.04	0.06	0.06
+1	0.05	0.05	0.06	0.05	0.06	0.08	0.08	0.06	0.10
+2	0.04	0.10	0.12	0.10	0.11	0.09	0.15	0.11	0.25
+3	0.09	0.17	0.20	0.15	0.21	0.18	0.30	0.15	0.55
+4	0.06	0.24	0.31	0.24	0.35	0.27	0.52	0.28	0.81
+5	0.11	0.35	0.48	0.33	0.50	0.41	0.73	0.41	0.92
+6	0.13	0.48	0.64	0.49	0.65	0.55	0.83	0.52	0.99
+7	0.16	0.63	0.80	0.60	0.80	0.66	0.94	0.64	1.00
+8	0.22	0.74	0.92	0.73	0.90	0.79	0.98	0.77	1.00
+9	0.27	0.83	0.97	0.84	0.97	0.86	1.00	0.87	1.00
+10	0.30	0.91	0.98	0.90	0.98	0.93	1.00	0.92	1.00

* surveys conducted every other year
Column A is the baseline analysis, using values derived from surveys conducted from 1998 to 1999 (Smith 2000b). These values are mean population estimate (N), S.D., number of surveys per year, and number of years it will take the trend to be detected. Columns B-I are the results produced by varying the initial values. Power estimates in bold face indicate the first estimate equal to or greater than 0.80 (0.79 is considered to be rounded up to 0.80) for that particular decreasing or increasing trend in N. See text for full discussion of results.

Variance could be lowered by 1) determining whether birds are marked or not 100% of the time, 2) covering more of the river on each survey, and 3) shortening the time frame of the surveys. The five-year average for the Elbow River was that 90% of the birds observed were determined to be marked or not; the three-year average for the Kananaskis River was 86%. Extra effort or more observers could increase this percentage. The use of unique nasal disk (small pieces of plastic of various colours and shapes attached through the nares) combinations to mark birds could increase the percentage to near 100%. However, some researchers have experienced up to

80% disk loss in two years (H. Regehr, pers. comm.) which reduces their usefulness for multi-year demographic studies. Current roadside survey routes cover about 40% of the designated stretch of the Elbow River and about 60% of the Kananaskis River. More survey effort (time and number of observers) would increase the amount of the river covered. Egg laying was estimated to begin as early as May 20 on both the Elbow and Kananaskis rivers (Smith 1999, 2000a). By conducting roadside surveys between May 5-20, rather than to June 15, the possibility of missing females who are laying eggs or already incubating is decreased, which should reduce the variance.

There are two fundamental aspects of using marked samples to estimate population size that need to be considered for long term monitoring. The first is whether the assumption of a closed population is true or not. Known individuals have been observed on both the Kananaskis and Elbow rivers in the same year, and some of the females with radio transmitters disappeared from the Kananaskis River valley for weeks, then were observed again (Smith 1999). This leads to the conclusion that the population is open, with movement in and out of the watershed. What proportion of the population is transient, and what impact this has on population estimates is unknown.

The second aspect to consider is whether the total marked population, from which the roadside surveys sample, is accurate over the long term. Each spring, before calculating a population estimate from the first survey, a mortality factor is applied to the marked population. This is to reflect the annual mortality that occurs, and is based on survival estimates from Banff National Park (Smith 1998). This, however, is an estimate and in some years there may be less mortality than other years. The marked population of males may be overcalculated; if a male's original mate dies he will attempt to re-pair (Smith et al. 2000) and would follow his new mate to her natal stream. Also, some females may not breed each year instead staying at the wintering area throughout the summer. These numbers are unknown, but estimated to be very few.

As a result the marked population may be overcalculated after a number of years, which could cause the population size to be underestimated. One method to attempt to avoid this problem is to conduct only two surveys within a short time frame. The first survey establishes the initial number of marked birds, and the second survey is the sample from which the population estimate is derived. For example, in 1999 MacCallum and Godsalve (2000) calculated the number of marked birds from surveys and banding conducted between May 11-21, then conducted a second survey May 25-28 from which they estimated the population. There are potential problems with this approach however. Because of the length of the stream reaches surveyed (60.4 km) both surveys are usually conducted consecutively over a number of days. It is possible that birds may move between reaches already surveyed and those yet to be surveyed, and as a result may be missed or counted more than once. In Banff National Park unpaired males moved up to 20 km (unpubl. data), and one nesting female moved 13 km between her nest site and feeding area daily (Smith 2000b). A one-day movement of approximately 17 km was also reported for a female on the McLeod River (MacCallum et al. 1999).

5.3 Analysis of Using Helicopter Surveys to Count Harlequin Ducks

As aerial surveys to count harlequin ducks have not been conducted in Kananaskis Country the results of surveys in the McLeod River watershed 1998-2000 (Kneteman and Hubbs 2000) were used to analyze the efficacy of the technique. To estimate visibility of harlequin ducks, aerial surveys were conducted on one of the same days as ground surveys, which took 2-3 days. When total counts were compared it was discovered that visibility from the air was = 70% of the ground counts in 1998 and 2000, and 13-27% in 1999. The low visibility in 1999 was attributed to bright light making it difficult to distinguish birds on the shining water. When the total aerial counts were compared to the two-sample population estimates calculated from the ground surveys (technique described above) the results were 51% in 1998 and 25% in 1999 (estimates were unavailable for 2000).

From the work of Kneteman and Hubbs (2000) it appears that aerial surveys have some utility for comparing counts among years but not in calculating a population estimate. The next step is to analyze the power of the aerial surveys to detect decreasing or increasing trends. To do this the mean count from 1998 and 2000 only were used, as poor light conditions affected the results in 1999. Table 4 shows that it would require one survey every year for seven years (seven surveys) to detect a 10% declining trend (column B, Table 4); if two surveys were conducted each year, then it would take five years (10 surveys; column C). With three surveys every year it would still take five years (15 surveys; column D) to detect the same trend. If the variance could be reduced to 2.5 then one survey could be conducted every year for four years (four surveys; column E). Two surveys per year would still take four years to detect the decline (eight surveys; column F). If the variance could be further reduced to 1.00 then it would still take one survey every year for four years (column I) to detect a 10% declining trend. Two surveys per year at 1.00 variance would require three years to detect the same trend (six surveys; column J).

Table 4. Power analysis of aerial surveys for estimating harlequin duck population size in the McLeod River/Whitehorse Creek watershed, Alberta.

Trend (%)	A	B	C	D	E	F	G	H	I	J	K
mean N	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5
S.D.	4.95	4.95	4.95	4.95	2.5	2.5	2.5	1.00	1.00	1.00	1.00
surveys/yr	1	1	2	3	1	2	2	1	1	2	2
years	3	7	5	5	4	4	6*	3	4	3	6*
-10	0.09	0.80	0.81	0.95	0.85	0.97	0.98	0.32	0.97	1.00	1.00
-9	0.08	0.73	0.74	0.91	0.78	0.93	0.97	0.32	0.94	1.00	1.00
-8	0.08	0.65	0.64	0.85	0.68	0.90	0.92	0.28	0.90	1.00	1.00
-7	0.05	0.54	0.57	0.78	0.61	0.81	0.89	0.26	0.85	0.99	1.00
-6	0.07	0.45	0.46	0.66	0.52	0.71	0.81	0.22	0.74	0.95	1.00
-5	0.06	0.40	0.34	0.51	0.40	0.55	0.67	0.18	0.65	0.88	1.00
-4	0.05	0.26	0.24	0.37	0.31	0.46	0.46	0.16	0.51	0.71	1.00
-3	0.05	0.19	0.16	0.25	0.20	0.25	0.32	0.11	0.33	0.49	0.94
-2	0.05	0.11	0.10	0.15	0.11	0.14	0.19	0.08	0.17	0.26	0.69
-1	0.05	0.07	0.07	0.08	0.08	0.09	0.08	0.06	0.10	0.10	0.27
0	0.05	0.04	0.05	0.04	0.05	0.04	0.06	0.05	0.05	0.05	0.06
+1	0.06	0.07	0.06	0.08	0.06	0.08	0.08	0.08	0.11	0.11	0.28
+2	0.06	0.16	0.12	0.14	0.14	0.17	0.20	0.09	0.24	0.24	0.77
+3	0.06	0.26	0.20	0.30	0.23	0.29	0.38	0.11	0.37	0.53	0.97
+4	0.06	0.39	0.33	0.50	0.40	0.48	0.60	0.16	0.58	0.78	1.00
+5	0.08	0.60	0.49	0.67	0.52	0.70	0.81	0.22	0.74	0.92	1.00
+6	0.06	0.75	0.67	0.86	0.70	0.85	0.93	0.25	0.87	0.98	1.00
+7	0.07	0.90	0.81	0.95	0.82	0.93	0.98	0.27	0.94	1.00	1.00
+8	0.07	0.96	0.91	0.99	0.91	0.98	1.00	0.34	0.97	1.00	1.00
+9	0.08	0.99	0.96	1.00	0.96	0.99	1.00	0.37	0.99	1.00	1.00
+10	0.08	1.00	0.98	1.00	0.98	1.00	1.00	0.41	1.00	1.00	1.00

* surveys conducted every other year

Column A is the baseline analysis, using values derived from surveys conducted from 1998 to 2000 (Kneteman and Hubbs 2000). These values are mean population estimate (N), S.D., number of surveys per year, and number of years it will take the trend to be detected. Columns B-K are the results produced by varying the initial values. Power estimates in bold face indicate the first estimate equal to or greater than 0.80 (0.79 is considered to be rounded up to 0.80) for that particular decreasing or increasing trend in N. See text for full discussion of results.

It may be difficult to improve the variance in the aerial surveys. However, it would be beneficial to conduct surveys exclusively during good lighting conditions and utilize the same experienced observers.

5.4 Comparison of Marked Sample Surveys vs. Aerial Counts

Kneteman and Hubbs (2000) suggest that aerial surveys are a more time- and cost-effective method for obtaining population counts than marked sample surveys, even in easily accessible areas, for the following reasons:

- a duck is less likely to be counted more than once in an aerial survey because they seldom fly ahead of the helicopter,
- aerial surveys can be conducted in areas of strong current or dense vegetation, or remote areas where ground access is difficult,
- an entire watercourse can be flown, reducing the effect of the issue of a closed or open population, and
- the length of time required is less (it took 1.9 hours to fly a section longer than the two ground surveys that each required 2-3 days to complete with three people/day; this does not include the time required to capture and mark birds).

The potential disruption to recreationists caused by helicopter surveys must be taken into consideration if planned for heavily used watersheds such as the Elbow and Kananaskis rivers.

If information is required for other population questions (such as survival rate, life span, rate of return, fidelity to stream sections, age of first breeding, intervals between reproduction, lifetime reproductive output or variability in individual production), then marking of individual birds will be necessary and the costs of doing so can be used in comparing the two techniques.

6.0 ESTIMATING PRODUCTIVITY

Waterfowl productivity estimates are based on pair and brood counts which furnishes an index provided three assumptions are met: (1) all breeding pairs and their broods are counted, (2) pairs that are counted do not produce broods elsewhere and (3) broods produced elsewhere do not move into the area (Cowardin and Blohm 1992). For pair counts females were utilized as they are the limiting sex and it is not always easy to determine pair status. Productivity estimates were based on the number of ducklings and adult females observed on the Elbow and Kananaskis rivers (Nichols 1991).

In the spring, observations from roadside/hiking surveys were used to determine the count of females on each river. During the third and fourth weeks of August brood surveys determined the number of surviving females and class 3 ducklings (fully feathered but flightless; Gollop and Marshall 1954). This time period was chosen since the water levels were lower resulting in increased visibility of birds and the females and broods were less likely to have migrated. These counts provide a relative index rather than an absolute number on a yearly basis, due to the facts that the spring count of females does not account for adult mortality during the summer or for emigration of non-breeding or failed breeding females back to the wintering area. Additionally, since ducklings are susceptible to predation until migration, the duckling count is likely estimated high.

From 1996 to 2000 harlequin ducks showed variable productivity on the Elbow and Kananaskis rivers (Smith 2001). This is common with all of the sea ducks (Goudie et al. 1994, Krementz et al. 1997). This high natural variation makes it difficult to apply significance to trends. It is useful to examine the net reproductive rate (R_0) — the average number of offspring produced by an average female over an average lifespan — as a measure of the rate of change of a population's size. If R_0 is > 2.0, there is a net surplus of offspring produced during each generation (replacing both the female and her mate); if $R_0 < 2.0$ then the population is not replacing itself and will decline (Gotelli 1995). The R_0 is calculated by multiplying the estimated adult survival rate (0.78) by the number of ducklings per female and sum these products across the reproductive life span. The reproductive life span is calculated as four years ($1.0 \div [-\ln 0.78] = 4$ years; as per Anderson 1975).

The estimated R_0 for the Elbow River declined from 6.24 to 1.18 between 1996 and 2000. The estimated R_0 for the Kananaskis River remained high at 3.90, 4.93 and 3.96 for 1998-2000 (Smith 2001). If the reproductive output on the Elbow River continues to be less than 2.0 then the population could be declining and this trend would be of concern. The Kananaskis River continues to produce a surplus of ducklings, with five of 12 females producing ducklings (n = 19) in 1999.

Kneteman and Hubbs (2000) estimated productivity on four rivers in 2000 by conducting aerial counts in the spring to determine the number of females, and aerial and ground surveys to detect females with broods. Ground surveys were conducted in early August while aerial surveys were conducted in early September. While their initial results suggest that similar numbers of ducks were observed on ground and aerial surveys, more comparative surveys need to be conducted. While adult ducks frequently respond to helicopters (or people on foot) by moving to stream centres, making them more visible, on ground surveys females with broods tend to hug the shoreline and hide under riparian vegetation whenever possible. There is no reason to expect them to react to helicopters differently. If so, then broods, and thus productivity, will likely be under-estimated on aerial surveys. A combination of aerial surveys in the spring to count adults, and ground surveys to count females with broods could be used, however a correction factor, equal to the difference in visibility between aerial and ground surveys, would have to be applied.

7.0 RECOMMENDATIONS

1. **Utilize aerial surveys to determine status of streams**: Determine the presence or absence of harlequin ducks on streams in the spring using this method. The first priority for surveying are those streams whose status is classified as “unknown”; the second priority are those classified as "potential" (Table 1). Identification of which stream reaches need to be surveyed should be done utilizing topographical maps, aerial photographs and local knowledge.

2. **Create a timetable for long-term monitoring in order to track trends**: Once the status has been determined, a timetable for monitoring the known breeding streams over five-to-ten-year periods should be established.

3. **Continue monitoring Kananaskis River to serve as a benchmark area**: Population counts and productivity estimates should be continued on the relatively undisturbed Kananaskis River to serve as a benchmark area. Since the purpose is to compare counts over a number of years to detect trends, aerial surveys are recommended. Brood surveys could be conducted

from the air also, however further comparisons need to be conducted between ground and aerial survey to determine if this is a suitable methodology for detecting females with young.

4. **Continue monitoring Elbow River to determine causes of declining productivity**: Population counts and productivity estimates should be continued on the Elbow River, to determine if the declining productivity is part of natural variation or if there may be human-caused stresses on the population.

5. **Monitor a stream that is subject to resource extraction**: Population counts and productivity surveys could be undertaken for a stream that is subject to resource extraction that impacts water quality (e.g., siltation that could impact the invertebrate food source) or impairs riparian habitat (used for loafing and nesting), as a comparison against the benchmark area. Cataract Creek would be a good candidate as it is a known breeding stream, and concerns have been expressed over the impact of logging activities in the upper watershed on water clarity and aquatic invertebrates (Smith 1997). Simultaneous monitoring of water quality and invertebrate composition and abundance should be undertaken.

8.0 CONCLUSIONS

Harlequin ducks are an integral part of aquatic ecosystems along Alberta's Eastern Slopes. The intensive research effort of the past six years has provided important baseline information about the species in Kananaskis Country. The adoption of a long-term monitoring plan for harlequin ducks will help ensure that this population is maintained in a sustainable state.

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