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Literature review and summary of research priorities for Harlequin Duck

A Report to:

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INTRODUCTION

The Harlequin Duck (*Histrionicus histrionicus*) is a small sea duck, which travels inland to breed on fresh water streams. Harlequins breed in western North America from Alaska and the Yukon south through western Montana to California (Harlequin Duck Working Group 1993); in eastern North America, they breed from Baffin Island south to eastern Quebec and Labrador (Goudie 1993). In the Palaearctic, they breed in Iceland, Greenland and Siberia (A.O.U. 1983). Approximately 110-150 pairs of Harlequins currently breed in Montana (Reichel and Genter 1994), with most located in the following areas: 1) tributaries of the lower Clark Fork River; 2) tributaries of the North, Middle, and South Forks of the Flathead River; 3) streams coming off the east front of the Rocky Mountains; and 4) the Boulder River (Miller 1988, 1989, Kerr 1989, Carlson 1990, Fairman and Miller 1990, Diamond and Finnegan 1992, 1993).

During the breeding season, Harlequins are found along fast mountain streams (Bengtson 1966). In many areas, Harlequins use streams with dense timber or shrubs on the banks (Cassirer and Groves 1990), but they are also found in relatively open streams along the east slopes of the Rocky Mountains, Montana (Markum and Genter 1990, Diamond and Finnegan 1992), and the Arctic tundra (Bengtson 1972). In Idaho, 90% of observations occurred near old growth or mature timber stands (Cassirer and Groves 1990). Mid-stream rocks, logs, islands, or stream-side gravel bars serve as safe loafing sites and appear to be important habitat components.

Most of the ducks arrive on their inland breeding areas in mid-April to early-May; unmated males typically arrive before pairs (Kuchel 1977). The males return to the coast shortly after the females begin incubation; most are gone by early July (Kuchel 1977). The females and young remain on the streams until August or early September. This chronology is influenced by elevation and by the timing of spring runoff; it may vary up to several weeks between years.

The U.S. Forest Service, Region 1, lists the Harlequin Duck as Sensitive (Reel et al 1989). The species is listed as a Species of Special Concern by the Montana (Montana Natural Heritage Program 1994) and Idaho (Idaho Conservation Data Center 1994) Natural Heritage Programs. The eastern North American population is listed as Endangered in Canada (Goudie 1993); the eastern and western populations are both listed under Category 2 as candidates for protection under the Endangered Species Act by the U.S. Fish and Wildlife Service (U.S. Department of Interior 1991).

The Montana Natural Heritage Program began surveying Harlequin Ducks in 1988. The survey data gave rise to questions involving site fidelity, productivity and mortality. We began individually marking Harlequins to a limited extent in 1991; through 1995, a total of 249 Harlequins were marked on 9 streams, representing the largest population of marked Harlequins from breeding streams. Birds marked in Montana have subsequently been captured and observed on the coasts of Oregon, Washington and British Columbia, with most reports coming from Vancouver Island. During that time, we observed 20 previously marked adults returning to Montana streams.

METHODS AND MATERIALS

All literature and reports in the Bibliography section were reviewed and evaluated. Contacts were made with members of Harlequin Duck Working Group and other knowledgeable individuals to determine current research projects and their applicability to sections in this report.

DISTRIBUTION

NORTH AMERICA

Breeding range. Figure 1, 2, 3. Breeds in two disjunct regions in North America. The Pacific population breeds from western Alaska, northern Yukon, northern British Columbia, and southern Alberta south to Oregon, Idaho, Wyoming, and east of the Continental Divide in Montana. The Atlantic population breeds from Baffin Island (at least formerly) through central and eastern Quebec, eastern Labrador, and northern Newfoundland. Occurs in summer in Mackenzie Valley and near Great Slave Lake, Northwest Territories (American Ornithologists Union 1983, Harlequin Duck Working Group 1993, 1994).

In the Rocky Mountains of the United States, Harlequins currently breed in western Montana (Reichel and Genter 1995), northern and southeastern Idaho (Cassirer and Groves 1994), and northwestern Wyoming (Wallen 1993, McEneaney 1994). Distribution within the area is shown in Figure 2. While much of Montana and Idaho has been surveyed (Figure 3), some areas with potential habitat have yet to be completed; surveying in Wyoming is less complete. As of 1995, surveys have been conducted on approximately 5,640 km of streams (Montana - 2,963 km; Idaho - 1,886 km; Wyoming 792 km) (Cassirer et al. 1996). Using habitat characteristics, accessibility, amount of human use, and nearby Harlequin Duck occurrences, streams were identified that had the highest potential for Harlequin Duck occurrence, for which no ducks had been observed; these included 31 in Montana, 16 in Idaho, and 41 in Wyoming (Cassirer et al. 1996).

In the literature and in unpublished reports, Harlequins within a geographical area often listed as "breeding on XX number of streams." This has been used differently by various authors to mean: 1) every named stream; 2) larger named streams; and 3) the major stream in an occupied drainage. Recently, biologists in Montana, Idaho, and Wyoming have written and adopted the standard Heritage Program definition of an "element occurrence (EO):" A drainage/portion of a drainage used by Harlequins where breeding is known or highly suspected (3 or more independent observations of females or pairs). The EO contains contiguous stream reaches used (and portions of lakes, reservoirs or bays, if regularly used) during the courtship, nesting, and brood-rearing periods, and not separated by more than 10 km of unsuitable habitat or 20 km of unoccupied habitat.

The breeding status on many streams with Harlequin Duck sightings has not been established in the Rocky Mountains of Montana, Idaho, and Wyoming. In Montana, there are currently 33 Harlequin Duck EOs and 32 streams where Harlequin Ducks have been observed or reported but on which the breeding status is unknown; these streams have been surveyed 0-5 times each (Cassirer et al. 1996.). In Idaho, there are currently 16 Harlequin Duck EOs and 24 streams where Harlequin Ducks have been observed or reported but on which the breeding status is unknown; these streams have been surveyed 0-5 times each (Cassirer et al. 1996.). In Wyoming, there are currently 8 Harlequin Duck EOs and 17 streams where Harlequin Ducks have been

observed or reported but on which the breeding status is unknown; these streams have been surveyed 0-5 times each (Cassirer et al. 1996.).

Winter range. Winters in the Aleutian and Pribilof islands south on the west coast of North America to Oregon, rarely to central California; southern Labrador, Newfoundland, Nova Scotia, south to Maryland (but mostly north of Cape Cod); accidental in Hawaii and the Great Lakes; much more abundant in the Aleutians than farther south in southwestern Canada and the U.S. Pacific Northwest (Figures 1).

OUTSIDE THE AMERICAS

Figure 4. In the Palearctic, the Harlequin Duck breeds in Iceland and Greenland in the Atlantic Ocean, and from the Lena River in Siberia east to Kamchatka and south to northern Mongolia, the Kurile Islands, and nothern Japan in the Pacific Ocean; winters in Eurasia south from the pack ice to the east coast of Korea and central Japan in the Pacific and on the Atlantic in the ice-free zones around Iceland and Greenland (Philips 1925, Salomonsen 1950, Dement'ev and Galdkov 1967, Portenko 1981, American Ornithologists Union 1983, Boertmann 1994).

HISTORICAL CHANGES

The range of the Harlequin Duck has contracted in the past 100 years at both large and small scales. Historically, Harlequins bred in Colorado, probably as a small isolated population, until at least 1883 (Parkes and Nelson 1976); currently, they do not breed in the state. In Oregon, Harlequins historically bred in the Wallowa and probably Blue Mountains of the northeastern part of the state (Gabrielson and Jewett 1940, Latta 1993). They are thought to have historically bred much more widely in the North Atlantic region (Merriam 1883, Peters and Burleigh 1951, Goudie 1989, 1993).

On a smaller scale, heavy white-water rafting is believed to have been the primary factor in the displacement and resulting extirpation of Harlequins on the Methow River in Washington (Brady pers. comm. *in* Clarkson 1994). In Yoho National Park, Alberta, Harlequins regularly bred in the vicinity of Lake Ohara until 1985; they have not been seen since then (Hunt and Clarkson 1993). This area now has heavy recreational use, building facilities, and a hiking trail circling the lake.

Within the Rocky Mountains of Montana, Idaho, and Wyoming, few historic records exist for either known current or extirpated Harlequin occurrences (Table 1). The scant existing evidence indicates that Harlequin Ducks were once more widespread than they are currently. In addition to the historic Montana, Idaho, and Wyoming streams listed in Table 1, Harlequins have not been observed during recent surveys of Big Creek, Quartz Creek, and Trout Creek, indicating that they may be extirpated from those streams (Table 2).

Table 1. U.S.A. Rocky Mountain streams previously used by Harlequin Ducks where no use has been documented since 1988 (Cassirer et al. 1996.)

State	Historical consistent use documented	Historical occasional breeding documented	Historical occasional pair use documented
Idaho	Kelly Creek and N. Fork Clearwater River below Kelly Creek (3)[1]	Smith Creek (Kootenai River) (3)[1]	Orogrande Creek (N. Fork Clearwater River) (4)[1]
Montana	Kootenai Falls area of Kootenai River (11)[1]	Otatso Creek	Bighorn River Canyon Jocko River Sweet Water Creek
Wyoming			Shell Creek Canyon

[1]Number in parentheses represents the number of surveys between 1989 - 1994

Table 2. Streams in Montana where Harlequins have not been observed during recent surveys.

Stream	Last year seen	Years surveyed since last seen
Big Creek (Kootenai R.)	1990	1991, 93, 94, 95
Quartz Creek (Kootenai R.)	1988	1989, 90, 95
Trout Creek (Superior)	1990	1991, 92, 93, 95

MOVEMENT

ON THE BREEDING GROUNDS

There is little published literature regarding movement within the breeding grounds. Kuchel (1977) found that pairs used lower McDonald Creek prior to establishing home ranges higher in the stream. Once established, pairs rarely moved more than 1-2 km, although movements of up to 8 km were recorded. Kuchel (1977) found unpaired males moved considerably more, with movements of up to 10 km found. In a reanalysis of Kuchel's (1977) data, Cassirer and Groves (1992) found that linear home ranges averaged 7.7 km (*SD* = 2.34) on McDonald Creek, similar to the 7 km reaches used in Idaho.

On the Bow River in Banff National Park, 5 pairs of birds were marked at what is probably a staging area or local migratory corridor (Smith 1996). Two pairs remained in a 2 km section of river where they were banded and another remained in a 2 km stretch about 12 km downstream; one pair remained within about 6 km until the female moved about 8 km up a drainage, perhaps to breed; the final pair moved about 15 km downstream within 22 days (Smith 1996).

In Montana and Idaho, several relatively long-distance movements in the past several years have been documented both within and between years (Table 3). The movement by the female and fledged brood to the Vermilion River was likely the result of disturbance due to marking (Reichel and Genter 1996). The female in Glacier Park has been seen at several locations over the 4 years since her banding (Ashley 1995); the locations in Table 3 are the furthest distance apart.

For 35 marked Harlequins, Bengtson (1972) found no movement overland between breeding streams and movement of only a few km within drainages. Not only did the birds return to the same drainage, but in 22 out of 33 cases, the birds were observed within 100 m of their locations during the previous year (Bengtson 1972).

Table 3. Significant movements of Harlequins within and between years on the breeding grounds (Cassirer and Groves 1994, Reichel and Genter 1994, 1996; Ashley 1995, Cassirer pers. comm.).

Sex and age	1st Date	Location	2nd Date	Location	Km moved
Adult Female 755-76007	8/4/92	Marten Creek, mouth of (w/ brood)	7/30/93	Swamp Creek, T25N R31W Section 9 (w/ brood)	16
Adult Female & 6 young 755-76013; 925-09336, 37, 38, 39, 40, 41	7/28/95	Marten Creek, near mouth of	7/29/95	Vermilion River	26
Adult Male 755-76075	5/26/93	Marten Creek, Devils Gap	4/27/95	Vermilion River, 0.1 mi above Miners Gulch	31
Adult Female 755-76025	8/10/92	McDonald Creek above McDonald Lake (w/ brood)	6/29/95	Middle Fork Flathead River (w/ brood)	18
Adult Female	5/85	Hughes Fork	7/17/91	Upper Priest River	?

MIGRATION

Nature of the migration in the species. All inland populations of the species migrate to coastal waters. A marked female seen on Granite Creek, Idaho on 17 July 1991 was relocated 13 days later off of Battleship Island in the San Juan Islands, Washington (Cassirer and Groves 1992). In Iceland, birds are thought to swim up the rivers from the coastal wintering grounds to the freshwater breeding sites (Gudmundsson 1961 *in* Bengtson 1966).

Timing and routes of migration. Harlequins, typically unpaired males, begin to arrive in Montana in mid-April (Kuchel 1977, Ashley 1994); the earliest record for Glacier National Park is

4 April 1970 on the Middle Fork Flathead River (Kuchel 1977:32). Pairs begin to arrive in late April and most are present by early May (Kuchel 1977, Ashley 1994). Two-year-old females may arrive later than older females (Ashley 1994; Kuchel 1977:32). Males begin leaving Montana by late-May, and are typically gone by late June (Kuchel 1977, Reichel and Genter 1993, Ashley 1994). Females may leave by early July if breeding is unsuccessful, and by mid-late July if successful; they often leave prior to their young fledging (Reichel and Genter 1996). Young birds leave last, beginning in early August, and nearly all birds are gone by the beginning of September (Ashley 1994).

In Washington, birds arrive on breeding streams in late March or early April (Schirato 1993). In Oregon, birds arrive on the breeding streams in late April, although some have been reported as early as late February (Latta 1993).

Of 249 Harlequins banded in Montana from 1991-1995, a minimum of 24 have been reported from Oregon (2), Washington (1), and southern British Columbia (21) including Vancouver Island and Hornby Island (Ashley 1995, Reichel and Genter 1996). Sexes and ages at banding show the following numbers and percentages observed: adult female (6, 11%), adult males (2, 5%), juvenile females (9, 7%), and juvenile males (7, 5%) (Ashley 1995, Reichel and Genter 1996). Two females radio-marked in Idaho were located in the San Juan and Gulf Islands of Washington and British Columbia, while one banded bird was reported from northwestern Washington (Cassirer and Groves 1994).

There are few records of birds between their breeding areas and wintering areas. A single marked bird has been observed en route between the breeding and wintering grounds (Cassirer and Groves 1991, Wallen 1993). She was originally marked in Wyoming and observed on the way back to the breeding stream on Crooked Creek, South Fork Clearwater drainage, in central Idaho (Cassirer and Groves 1991). She was seen about a week later in Grand Teton National Park and had nested successfully. The only known wintering bird marked in Wyoming was observed off San Juan Island in Washington in August 1989; he returned to Grand Teton National Park as an unpaired male in 1990 (Cassirer and Groves 1991, Wallen 1993).

Migratory behavior. It is believed that nearly all one-year-old birds, and some (perhaps most) two-year-old birds remain in coastal water, not moving to breeding streams until they are 2-4 years of age.

HABITAT PARAMETERS

BREEDING RANGE: TERRESTRIAL

Throughout their range, Harlequin Ducks use a wide variety of habitat types during the breeding season. Typically they are found on swift, clear streams in a variety of habitats ranging from old growth to second growth to arctic tundra (Philips 1925, Salomonsen 1950, Bengtson 1966, Dement'ev and Galdkov 1967, Inglis et al. 1989, Cassirer and Groves 1991, Diamond and Finnegan 1993, Cassirer and Groves 1994, Ashley 1994). They also apparently breed in coastal estuaries of British Columbia (Breault 1993), Alaska, and Russia (Portenko 1981). though this phenomenon is poorly studied or understood.

Overstory. In Idaho, Harlequins were strongly associated with mature to old-growth western red cedar/western hemlock (*Thuja plicata/Tsuga heterophylla*) forest (Cassirer and Groves

1994). Likewise, in Glacier National Park, ducks were seen primarily in areas with old-growth or mature overstory (90%); note however that this figure is approximately in proportion with habitat availability (Ashley 1994). Near Prince William Sound, Alaska, 10 nests were located in 1991-93; they were all associated with old-growth forest (Crowley 1994). In Oregon, however, old-growth accounted for only 48% of sightings (Thompson et al. 1993). On the Rocky Mountain Front of Montana, more birds were seen in pole sized timber (38%) than in other size classes, including mature and old-growth combined (26%) (Diamond and Finnegan 1993); tree composition was evenly split between Douglas fir, lodgepole pine and Englemann spruce. On the Olympic Peninsula of Washington, there appeared to be no selection of particular forest types (Schirato and Sharpe 1992).

Stream reaches where Harlequins were observed in Idaho were usually not logged or had an unlogged buffer along the stream (Cassirer and Groves 1994).

Bank composition. In Glacier National Park, most Harlequin observations were adjacent to banks covered with a combination of trees and shrubs; because this was also the most common bank cover type in the park, selection was not evident (Ashley 1994). However, pairs did select for areas with overhanging vegetation ($X^2 = 5.185$, $p = 0.023$) and against areas with undercut banks ($X^2 = 4.596$, $p=0.032$) (Ashley 1994). On the Rocky Mountain Front of Montana, birds were most commonly seen along banks covered with shrub/tree mosaic (23%) or gravel (20%) (Diamond and Finnegan 1993); locations for most observations did not have overhanging vegetation (70%) or undercut banks (81%). In Idaho, adult and brood use of banks, by cover type, was similar: trees 40%, shrubs 21%, mosaic 20%, grass/forb 7%, rock/sand/silt 6%, and woody debris 1% (Cassirer and Groves 1994). In Oregon, most banks had trees (41%) or shrubs (25%) present (Thompson et al. 1993). Undercut banks were present at only 18% of sighting locations in Oregon (Thompson et al. 1993). Overhanging vegetation was present at 57% of sighting locations in Idaho (Cassirer and Groves 1994) and 73% in Oregon (Thompson et al. 1993).

In Grand Teton National Park, Harlequins selected banks dominated by shrubs (71%) and signicantly avoided banks dominated by grass/forbs (3%) or trees (11%) (Wallen 1987:66).

BREEDING RANGE: AQUATIC

Stream width. On McDonald Creek in Glacier National Park, Montana, Harlequins appeared to select narrow (<15 m wide) stream locations, although the average stream width was 19 m (Ashley 1994). In western Montana, 7 other streams with Harlequins ranged from 5-30 m in width (Fairman and Miller 1990). On the Rocky Mountain Front of Montana, most Harlequins used streams 6-10 m wide (48%), while the rest used larger (26%) and smaller (25%) streams (Diamond and Finnegan 1993).

Stream width at most Harlequin observation sites in Idaho was less than 10 m; streams used by juveniles were significantly smaller than those used by adults (Cassirer and Groves 1994), though a seasonal adjustment was not made. Stream width at most Harlequin observation sites in Oregon averaged 13.5 m (range 2-50 m) (Thompson et al. 1993). Stream widths of breeding streams in Iceland ranged from 2-40 m; those streams were typically shallow (0.5-1.0 m) (Bengtson 1972).

Stream gradient. In western Montana, 7 streams with Harlequins had gradients ranging from

1.8-2.8% (Fairman and Miller 1990). Stream gradients at most Harlequin observation sites in Oregon were between 1-7%. (62% of observations), while most others were in low (<1%) gradient areas (33% of observations) (Thompson et al. 1993). On the Olympic Peninsula of Washington, Harlequins select stream reaches with 1-7% gradient; birds were not present in lower portions or steep headwater sections of occupied streams (Schirato and Sharpe 1992). In Grand Teton National Park, Wyoming, Harlequins used the lowest gradient streams in the park, averaging less than 7% (Wallen 1987).

On the Rocky Mountain Front of Montana, Harlequins were observed at sites with stream velocities ranging from 0.8 m/sec to 4.1 m/sec; the average was 1.3 m/sec (n=42) (Diamond and Finnegan 1993). In Idaho, Harlequin Ducks were strongly associated with swiftly flowing streams, however, adults were found in higher average velocity (1.2 m/sec) locations than were broods (0.9 m/sec) (Cassirer and Groves 1994). Stream velocity of breeding streams in Iceland ranged from 0.5-3.0 m/sec (Bengtson 1972).

Channel morphology. On McDonald Creek in Glacier National Park, Montana, Harlequins used straight, curved, meandering, and braided stream reaches in proportion to their availability (Ashley 1994). On the Rocky Mountain Front of Montana, most Harlequins used streams that were controlled by v-shaped valleys, either straight (34%) or curved (29%) (Diamond and Finnegan 1993). In Oregon, 45% of sightings were in straight channels (Thompson et al. 1993). In Grand Teton National Park, Wyoming, more than 50% of all Harlequin observations were made in meandering stream channel types (Wallen 1987).

Aquatic habitat. In Glacier National Park, Kuchel (1977) found that Harlequin adults selected stream habitats over backwater habitats during the first week of May, but that selection was reversed during 12 June - 2 July ($p < 0.01$). Bottom types were randomly selected except during the period 8-14 May when cobble was selected (Kuchel 1977, Ashley 1994). The strongest selection was for stream reaches with 3+ loafing sites per 10 m (Kuchel 1977, Ashley 1994). However, during brood rearing, 83% of observations during the second week occurred in backwaters, which increased to 91% by the time broods were 6 weeks old (Kuchel 1977); this is not evident in Ashley's (1994) data. Broods generally moved downstream as they got older (Kuchel 1977).

On the Rocky Mountain Front of Montana, most Harlequins used riffles (25%), rapids (24%), or runs (24%); observations were not separated by season (Diamond and Finnegan 1993). Similarly, in Idaho, adults used riffle, run, and rapid areas 74% of the time, while broods used pocketwater and pool/backwater 50% of the time (Cassirer and Groves 1994). In Oregon, adults also used riffle (21%), run (22%), and rapid (22%) areas equally, while pocketwater, pools, glides, and backwaters were used substantially less (Thompson et al. 1993).

In Iceland, Harlequins overall selected "calm" water as opposed to "fast" or white" water ($X^2 = 42.4$, $p < 0.001$); however, they preferred to feed in "fast" water ($X^2 = 32.4$, $p < 0.001$) (Inglis et al. 1989).

In Montana, bays at the mouths of some breeding streams and lakes are occasionally used by foraging and loafing Harlequins and may provide night roosting areas late in the brood rearing season (Reichel and Genter 1996). There are multiple records of broods using lakes in British Columbia, but the extent and timing of use is unknown (Campbell et al. 1990, Breault and Savard 1991). In Alaska, estuaries and intertidal deltas provided habitat for foraging and loafing

Harlequins (Crowley 1994).

Substrate. In Idaho and Oregon, Harlequins were typically associated with cobble and boulder substrates (Thompson et al. 1993, Cassirer and Groves 1994); there was no difference between substrate chosen by adults and broods (Cassirer and Groves 1994). Substrates on the Rocky Mountain Front of Montana were primarily cobble (62%), boulder (17%), or bedrock (10%) (Diamond and Finnegan 1993). While most Harlequins were observed on gravel and cobble substrates in Grand Teton National Park, use of those substrates was not significantly different than their availability (Wallen 1987).

Woody material was present at 85% of duck sightings in Oregon, with the most structures being ramps (42%) and drifts (25%) (Thompson et al. 1993). Similarly in Idaho 77% of sightings were near woody debris (Cassirer and Groves 1991). On the Rocky Mountain Front, however, less than 40% of the observation locations contained woody debris and 19% contained only a single piece of woody debris within 10 m (Diamond and Finnegan 1993).

Loafing sites. Loaf sites, places where Harlequins will haul out of the water to rest, are consistently mentioned in the literature and unpublished reports as being important components of Harlequin Duck stream habitat. In Grand Teton National Park, Wyoming, Harlequins significantly selected for sites with >3 loaf sites per m, and avoided areas with no loaf sites (Wallen 1987). On the Rocky Mountain Front, over 70% of Harlequin observations were in areas with 2 or more loaf sites per 10 m (Diamond and Finnegan 1993). Harlequins in Idaho were within 10 m of multiple loaf sites 83% of observations for adults and 94% for juveniles (Cassirer and Groves 1994). Moss covered midstream boulders were used most often in Oregon, with an average of 5 loaf sites per 10 m at observation sights (Thompson et al 1993, 1993).

In Iceland, Harlequins spent 47% of their time on larger islands, only 24% on rocks protruding above the river, and <1% on the banks of the river (Inglis et al. 1989).

Quality. Streams used by Harlequins in northern Idaho, Montana, and Wyoming (n = 11) were more alkaline than unused streams (x $CaCO_3$ = 58 m/l, x $CaCO_3$ = 8 m/l, $p = 0.004$) (Cassirer and Groves 1994).

There are two records of broods using glacial streams or lakes in British Columbia (Breault and Savard 1991).

Quantity. Volume discharge was the most important factor separating used from unused streams in Prince William Sound, Alaska; volume discharge averaged 3.2 m/s on used streams (Crowley 1994). The largest streams in Prince William Sound were not used by breeding Harlequins; smaller salmon streams were also avoided by nesting females (Crowley 1994). See also ***Causes of death.***

Food availability. Streams used by Harlequins averaged a higher standing crop of benthic macroinvertebrate biomass in Idaho ($x = 0.52$ g/m^2) than unused streams ($x = 0.34$ g/m^2) (Cassirer and Groves 1994); there was considerable overlap, however, and the differences were not significant. Bengtson (1966) believed that the distribution of Harlequins in Iceland was determined by the availability of suitable food, particularly Simuliidae larvae. In Iceland, Bengtson and Ulfstrand (1971) reported high numbers of non-breeding females on the breeding streams in 1970; this was correlated with a far below normal standing crop of favored invertebrate food species. More research revealed that numbers of Harlequins produced from 1977-85 were correlated with biomass of blackflies (*Simulium vittatum*) present (Gislason and Gardarsson 1988,

Gardarsson and Einarsson 1993 *in* Gislason 1994).

Other. Concentrated Harlequin Duck use occurs on several stream reaches in Montana believed to share certain hydrologic characteristics; in particular, stream reaches supporting notable breeding success are observed to receive locally high rates of groundwater discharge (Reichel and Genter 1996). This has also been noted in British Columbia (Clarkson 1992, Hunt 1993). Some of the densest known Harlequin breeding populations occur in Iceland on the River Laxa which is the outlet of Lake Myvatn; this lake is spring fed, resulting in very stable flows, with almost no flooding (Bengtson and Ulfstrand 1971, Gardarsson et al. 1988). Groundwater discharge may influence Harlequin success by affecting flow regimes, thermal characteristics, geochemistry and nutrient status, macroinvertebrate fauna, or a interaction of these factors.

WINTER (NON-BREEDING) RANGE

In Iceland, birds primarily use rocky areas with breaking surf (Bengtson1966). In British Columbia, they are found in often turbulent waters near rocky islets, shores, and bays where they frequently feed in kelp beds (Campbell et al. 1990).

BREEDING

PHENOLOGY

Pair formation. Pair formation in Washington took place on the wintering grounds beginning in October and was completed by early February (Fleischner 1983). In Iceland, about 10% of birds were paired by December (Bengtson 1966). Copulation occasionally takes place on the British Columbia coast in early April (Pearse 1945).

Nest building. In Iceland, females begin looking for a nest site 1-2 weeks prior to egg laying (Bengtson 1966).

Egg laying. In Montana, egg laying takes place between 30 April and 4 July, with most occurring between 10 May and 10 June (Kuchel 1977, Reichel and Genter, unpubl. data). Dates on which clutches have been found in British Columbia range from 24 May to 24 June; backdating indicated that the earliest clutch was laid on 17 May (Campbell et al. 1990). Egg laying in Iceland takes place between 10 May and 8 July, with most occurring in early June (Bengtson 1966).

Hatching. Thompson et al. (1993) reported hatching at two nests on 2-10 June and 10 July. Kuchel (1977) estimated hatching dates for broods on McDonald Creek, Glacier National Park: 13 of 15 occurred between 27 June and 7 July with the extremes on 11 June and 2 August. In Iceland, young begin to appear in early July (Bengtson 1966). Dates of all ages of brood records in British Columbia range from 16 June to 13 September, with 53% between 10 July and 12 August (Campbell et al. 1990).

Postbreeding. Young in Montana fledged between 15 July and 10 September, with most fledging between 25 July and 15 August (Kuchel 1977, Reichel and Genter, unpubl. data).

NEST SITE

Few nests have been located in the Pacific population; two nests were on rocks, six were on the ground, two were on cliff faces, two were in piles of woody debris adjacent to streams, two were in tree cavities, and one was in a cavity on a cliff face. In Montana, a nest was found on a

limestone cliff, 6 m above the river (Diamond and Finnegan 1993) and another in a log jam at the top of a waterfall (Thompson 1985). Cassirer et al. (1993) reported three cavity nests located 0, 0.3, and 14 m from the water (one was 25 m from the main channel). Jewett et al. (1953) reports a nest on sand and gravel on the Nisqually River, Washington on 26 May 1920; the nest was not concealed. A nest in Oregon was reported in debris on an overturned stump of alder in mid-stream (Gabrielson and Jewett 1940). Three additional nests from Oregon were on the ground and well-camouflaged by low vegetation (Latta 1993, Thompson et al. 1993). In British Columbia, only 4 nests have been found and were located on: 1) the ground under bushes at the foot of a small Douglas fir less than 1 m from the creek bank; 2) the ground under a root overhang, in a depression in a newly formed creek bank; 3) a cliff ledge directly over the river; and 4) a 2 m tall rock just off an island (summarized in Campbell et al. 1990).

In Alaska, 10 nests were located on steep, southwest-facing, sloping stream banks of small, first-order tributaries timberline; all were beneath old-growth canopy in shallow depressions or cavities and associated with woody debris and shrubs (Crowley 1994).

In Washington, interviews with a collector who observed approximately 41 nests indicated that 90% occurred on mid-channel islands which were used in multiple years (Schirato 1993). Jewett et al. (1953) reported two nests from Washington, one on a rocky point of a stream, the other on an open island.

In Iceland, the availability of nest sites may be a secondary factor in determining Harlequin distribution (following food availability) (Bengtson 1966). They prefer to nest on inaccessible islands in swift streams; they may also be located in caves or holes in lava or under dense brush (Bengtson 1966). Of 98 nests in Iceland, 66 were on islands and 32 were on river banks; only 7 were more than 5 m from water (Bengtson 1972). The nests were typically located in dense shrubs (71 of 98), with some in scattered shrubs (11), grass and forbs (8), and rocks and cavities (10) (Bengtson 1972).

Nest sites are sometimes reused (Schirato 1994, Thompson 1985).

Harlequins were rarely seen at nest sites; rather, they were almost always seen downstream (Cassirer et al. 1993).

EGGS

Clutch size. In Montana, a clutch of 5 was reported (Diamond and Finnegan 1993), four clutches of 6, 6, 7, and 7 were reported in British Columbia (Campbell et al. 1990), and 2 clutches of 7 in Washington (Jewett et al. 1953). In Iceland, 77 complete clutches averaged 5.7 eggs with a range of 3-9 (Bengtson 1972). There was a seasonal decline in clutch size (Bengtson 1972). The mean number of eggs to hatch from successful nests was 5.3 (Bengtson 1972). The only Greenland clutch size reported is 8 (Salomonsen 1950).

Egg laying.

When started in relation to nest completion. No availbe information.

Time of day and rate of deposition. Bengtson (1966) followed three nests and found that intervals between eggs were 2-4 days, with 3 days being the most common interval and with 4 days rare.

INCUBATION

Onset of broodiness and incubation in relation to laying. Incubation starts prior to completion of the clutch (Bengtson 1966).

Incubation period. Thompson et al. (1993) reported one nest which took at least 37 days (3 June-10 July) and another which took at least 24 days (10 May to 3-10 June). Bengtson (1972) found an average incubation period (laying of last egg to hatching of last egg) of 28 days (n=4, range 27-29) in Iceland.

Parental behavior.

Roles and attention to eggs and incubating mate. Only females incubate eggs (Bengtson 1966).

Incubation rhythm, duration of attentive periods. Bengtson (1966) reported on a female who was away form the nest for about 2 hrs. He felt that females only fed about once every 48 hrs.

DEMOGRAPHY AND POPULATIONS

MEASURES OF BREEDING ACTIVITY

Age at first breeding; intervals between breeding. Very few 2-year-old males have been reported on the breeding grounds in North America. Yearling males make up 1-2% of the population on the breeding grounds in Iceland (Bengtson 1972, Gardarsson 1979). In Montana, no males have been reported on breeding streams prior to attaining fully adult plumage at 3-years-old (Phillips 1925, Reichel and Genter 1996).

The youngest female known to have bred is a single 2-year-old, although nine additional non-breeding 2-year-olds have been observed on natal streams and thirteen marked 2-year-olds are known to have been alive (Reichel and Genter 1996).

Some females on breeding streams apparently do not lay eggs (Bengtson and Ulfstrand 1971, Dzinbal 1982, Wallen 1987, Cassirer and Groves 1991). Bengtson and Ulfstrand (1971) classified 15-30% (n=48) of adult (by bursae inspection) females as non-breeders, and found that 87% of all clutches were successful; therefore, approximately 90% of non-breeding females did not even attempt to breed in Iceland. Additionally, examination of ovaries of 6 non-breeding females showed that none had lain eggs (Bengtson and Ulfstrand 1971). Many of these non-breeding "adults" may have been young (2-3 year-old) birds since cloacal examination gives adult status to 2-year-olds. However, in Iceland, Bengtson (1966) believed that 2-year-old females Harlequins did not regularly go to the breeding grounds. Dzinbal (1982) estimated that 53-95% of females not producing broods did not attempt to breed; those results may have been due to use of patagial markers negatively affecting breeding behavior (Bustnes and Erikstad 1990). Wallen (1987) reported that some females left the breeding stream at the same time as their mates; unpaired females arrived about 4 weeks later than pairs, did not breed, and left after 3-5 weeks.

Clutch size. Twelve clutches from the Pacific Northwest averaged 6.25 eggs (range 3-7) and are listed below. In Montana, a clutch of 5 was reported (Diamond and Finnegan 1993), four clutches of 6, 6, 7, and 7 were reported in British Columbia (Campbell et al. 1990), and 2 clutches of 7 in Washington (Jewett et al. 1953). Cassirer et al. (1993) reported on 3 nests with 3, 5, and 7 eggs in Idaho. Thompson et al. (1993) reported 2 nests, each with 7 eggs, in Oregon, while Gabrielson and Jewett (1940) reported a clutch of 6 eggs on 30 May 1931 on the Salmon River near Zigzag. In Iceland, 77 complete clutches averaged 5.7 eggs with a range of 3-9 (Bengtson

1972). There was a seasonal decline in clutch size (Bengtson 1972). The mean number of eggs to hatch from successful nests was 5.3 (Bengtson 1972). A single known Greenland clutch was 8 (Salomonsen 1950).

Annual and lifetime reproductive success. In Montana during 1989-1994, annual numbers of ducklings fledged per adult female averaged 1.60 and ranged from 0.84 - 3.15 (n=230 adult females) (Reichel and Genter 1995). Brood size of Class I-IIb young (Bellrose 1976) averaged 5.1 on the Rocky Mountain Front (Diamond and Finnegan 1993), while throughout Montana, size IIc to fledging averaged 3.57 and ranged from 2.81 - 5.86 (n=103 broods) (Diamond and Finnegan 1993, Reichel and Genter 1995). Average brood size at fledging in Glacier National Park during 1973-75 ranged from 2 to 4.25 (n=8), while numbers of young fledged per adult female ranged from 0.1 - 1.3 (Kuchel 1977:72-73).

Broods ranged from 1-6 in Oregon and averaged 2.7 (n=26) (Thompson et al. 1993, 1994). These sightings, however, were spread throughout the breeding season and therefore should not be considered the same as numbers fledged.

In Idaho, number of ducklings fledged per adult female ranged from 0.7 - 1.3 and averaged 1.2 (n=14); number of females producing broods was 29% in 1990 (Cassirer and Groves 1991, 1994). Average brood size was 3.4 (range 1-7) in Idaho (n=24) (Cassirer and Groves 1991).

In British Columbia, 41 broods of all ages ranged in size from 1 - 10 (1Y-3, 2Y-3, 3Y-5, 4Y-11, 5Y-14, 6Y-2, 7Y-1, 8Y-1, 10Y-1); the brood with 10 young was apparently from a single female (Campbell et al. 1990).

In Alaska, numbers of young per breeding female and per adult female were respectively 1.5 and 0.8 in 1979, and 0.6 and 0.3 in 1980; patagial tags on adults $$ appeared to have caused poor reproductive success (Dzinbal 1982).
Non-breeding frequency of females was 47% in 1979 and 50% in 1980 (Dzinbal 1982).

In Iceland, 1.73 (85:49) and 2.43 (120:49) young per adult female were successfully raised respectively during 1975 and 1976 (Gardarsson 1979). In an increasing population in Iceland, productivity ranged from 0.1 to 3.3 (x = 1.1) ducklings fledged per hen per year over 15 years (Gardarsson and Einarsson 1991). This was similar to that found by Bengtson (1972) who reported 0.0 to 3.8 young per adult female on 4 rivers during 4 years.

Proportion of total females that rear at least one brood to nest-leaving. The proportion of females successfully raising a brood in a single year, varies widely between years. Reported numbers range from 12-56% (Bengtson and Ulfstrand 1971, Kuchel 1977, Wallen 1987, Cassirer and Groves 1991, Reichel and Genter 1995). In Montana, 230 females observed between 1989 and 1994 raised 103 broods for an average of 44.8% (range 24-55%) (Reichel and Genter 1995).

Sex ratio. Cassirer (1995) found a spring adult sex ratio of 1.31:1 (m:f, n = 81) in 1995 on Idaho streams. In Banff National Park, Alberta, sex rations varied from 1.37:1 in May to 1.81 in June (Smith 1996). In Iceland, sex rations on the breeding grounds varied from 54-70% males during 5 summers in late May - early June (Bengtson 1966, Bengtson 1972, Gardarsson 1979).

In coastal British Columbia the apparent sex ratio is 1.5:1 (544 birds) in winter declining to 1.4:1 (297 birds) in March-April (Campbell et al. 1990); this grows to 4.3:1 in May and by July, when adult females are still on the breeding streams, it reaches 18.2:1 (1633 birds).

LIFE SPAN AND SURVIVORSHIP

In Glacier National Park, all mortality of ducklings (through fledging took place in the first three weeks of life (Kuchel 1977). This is similar to the findings of Bengtson (1966, 1972) who reported that of 7 broods totaling 37 ducklings, 24 survived 1 week, 19 two weeks, and little mortality was seen after two weeks. Bengtson (1972) reported that survival of ducklings ranged from 40-76% on 3 streams over 5 years.

In Montana, 249 Harlequins (39 adult males, 53 adult females, 157 juveniles) have been banded from 1991 through 1995 (Reichel and Genter 1996). Of 58 juveniles marked in 1992, at least 12 females and 2 males were alive in 1994, and 8 females and 2 males in 1995; of 42 juveniles marked in 1993, at least 1 female was alive in 1995. Both males known to be alive were seen on the wintering grounds. Adult males returned to the breeding streams when they were alive the previous year 53% of the time while females returned at a rate of 57%. The higher female rate may be due to the fact that a male may mate with a new female, which could lead him to a new stream, and thus he would not be seen on the previous year's stream.

In Idaho, 63% of adults (n=30) returned at least 1 year; male and female rates were not significantly different (Cassirer and Groves 1994); one duck marked as an adult in 1988 returned through 1993 (minimum 7 years old). No ducklings marked from 1988-1991 were re-observed (n=27). In Wyoming 40% of marked adults returned to breeding streams (Wallen 1993). At least 5 females of 103 ducklings banded in 1987-1990 have returned and nested successfully (Wallen 1991). The oldest known Wyoming bird was marked as a duckling in 1985 and recaptured in 1991 (Wallen 1993). In Alaska, 30% (8) adult females and 30% (3) of adult males marked were relocated the following year (Dzinbal 1982:62).

In Iceland, 64% (20) adult females and 48% (13) of adult males, marked with nasal discs, were relocated the following year (Bengtson 1972). Hatching success in Iceland averaged 87% and ranged from 84% to 91% in four years (Bengtson 1972).

CAUSES OF MORTALITY

Causes of death. In Montana, high water during early summer runoff was associated with low productivity (Kuchel 1977, Diamond and Finnegan 1992, 1993, Reichel and Genter 1993, 1995). Wallen (1987) reported that following a severe July rainstorm which raised a creek level 0.6 m within 2 hours, both broods seen prior to the storm were never seen again; however, he generally felt that drought in Grand Teton was more limiting to reproductive success than flooding. Dzinbal (1982) reported higher spring run off was associated with lower reproduction in a two-year study in Alaska. In Idaho, productivity was negatively correlated to June stream flow ($r = -0.93$, $p = 0.006$) (Cassirer and Groves 1995). It is currently not understood what causes this correlation. Possibilities include females not nesting due to high water and/or poor feeding; destruction of nests within the floodplain; or loss of juveniles due to drowning, being separated from the female, inability to feed effectively, or hypothermia.

Bengtson (1972) found very low duckling survival coincided with adverse weather and very low abundance of blackflies, their preferred food in his study area.

In coastal waters, Harlequins are occasionally caught by large mussels and clams by the bill and drowned (Turner 1886 *in* Philips 1925)

Exposure and predation. Predation on eggs by river otters and black bears has been reported from Washington (Jeff Foster, unpubl. data, *in* Schirato 1993).

Following mink (*Mustela vison*) introduction to Iceland, Harlequin populations substantially declined in several areas, and changed nesting sites in others (Bengtson 1966). Predators took 9 nests in Iceland (n=89) and included Raven (5), mink (2), Arctic Skua (1), and arctic fox (1) (Bengtson 1972). Additionally 2 nests were deserted and 1 failed to hatch (Bengtson 1972). Arctic Skuas were seen taking 2 chicks in Iceland (Bengtson 1972).

RANGE

Dispersal from natal stream. All juveniles leave the natal stream soon after fledging (Reichel and Genter 1996, Cassirer and Groves 1994). Of 100 ducklings banded in Montana in 1992-93, seven males marked as juveniles were seen only on the coast; none have been reported from their natal stream (Ashley 1995, Reichel and Genter 1996).

In Alaska, one brood was reported to use a Stellar Lake when very young, moving down to Stellar Creek when older, and finally used Stellar bay and the lower tidal portion of Stellar Creek when Class IIc-3 (Dzinbal 1982).

Fidelity to natal stream. Of 100 duckling marked in 1992-93 in Montana, 14 females are known to have survived at least 2 years. Of the 14 surviving females, 5 were reported only from their natal stream, 1 only from the coast, and 8 both on the coast and the natal breeding stream. Seven males marked as juveniles were all seen only on the coast; none have been reported from their natal stream (Ashley 1995, Reichel and Genter 1996). In Glacier National Park, 2 of 5 ducks banded as juveniles in 1974 returned to the natal stream in 1976; both were females (Kuchel 1977).

No ducklings marked from 1988-1991 in Idaho were re-observed (n=27).

POPULATION STATUS

Estimates or counts of density. Densities of Harlequins on breeding streams range from 0.05 pairs/km on a stream in Montana (Diamond and Finnegan 19930 up to 8.5 pairs/km on part of the Laxa River in Iceland (Bengtson and Ulfstrand 1971). In Montana, pair density on a 16 km section of McDonald Creek was 0.67 pair/km in 1974 and 0.91 pair/km in 1975 (Kuchel 1977). On the Rocky Mountain Front, densities ranged from 0.05 pairs/km to 0.21 pairs/km (Diamond and Finnegan 1993).

In Idaho, pair densities averaged 0.19 pairs/km (range 0.08-0.57) of occupied streams surveyed (Cassirer 1995). From 1990 through 1992, densities there averaged 0.06-0.53 pairs/km ($\bar{x}$ = 0.22) (Cassirer 1993). In Oregon, densities of adults per km surveyed ranged from 0.07 to 1.21; densities per km surveyed including juveniles ranged from 0.07 to 2.37 (Thompson et al. 1993, 1994).

On the Bow River in Banff National Park, densities observed were the highest known from streams in North America, ranging from 2.4 ducks/km on a 15 km reach to 6.2 on a 16 km reach (Smith 1996).

On Kodiak Island, Alaska, density of breeding Harlequin pairs ranged from 0.63 pairs/km along the Ayakulik River to 1.98-7.24 birds/km in 3 coastal bays (Zwiefelhofer 1994). Dzinbal (1982) reported 1.3-1.8 pairs/km on two small coastal streams in Alaska.

On the Laxa River in Iceland, Harlequins are apparently at densities higher than other known stream populations (Bengtson 1972). Twenty populations in Iceland ranged from 0.2 to 8.5

pairs/km, with an average of 0.9 pairs /km (Bengtson and Ulfstrand 1971, Bengtson 1972).

In eastern Siberia (Kistschinsky 1968 *in* Bengtson 1972) found 1.1 pairs/km and 0.8 - 1.2 broods/km.

Numbers. Numbers estimated by most recent publications and reports are described in Table 4. The largest reported single Harlequin Duck occurrence (see ***Breeding Range***) is from the Bow River drainage in Banff National Park where 215 individuals were calculated to occur during 1995 using a mark/resight model (Smith 1996).

Table 4. Estimated numbers of Harlequin Ducks.

Location	Estimated Breeding Population	Minimum # Pairs	Estimated # Pairs	Citation
Atlantic Ocean	?			
Greenland	?			
Iceland	?			
North America	<1,000			Goudie 1991
Pacific Ocean (Asia)				
Russia	50,000 - 100,000			
Japan	?few			
Pacific Ocean (North America)	165,000			Goudie et al. 1994
Lower 48 U.S. States		523	758	Cassirer et al. 1996
Washington		274	399	Schirato 1994
Montana		110	159	Reichel and Genter 1996
Oregon		50	72	Thompson et al. 1993
Idaho		48	70	Cassirer et al. 1996
Wyoming		40	58	Cassirer et al. 1996

Trends. Little data is available either long or short term. The Atlantic population has undergone and is continuing to undergo significant declines (Harlequin Duck Working Group 1993). In the North American Pacific populations, the trend is less clear cut. Christmas bird counts in British Columbia show declines at 5 locations and increases at 3; the increases may be

due to increasing numbers of observers in urban areas (Harlequin Duck Working Group 1993). In Alberta breeding Harlequins are significantly declining on the Maligne River in Jasper National Park (Harlequin Duck Working Group 1993). Seven streams in Northern Idaho appear to be stable though 1 stream shows a decrease and one an increase; all populations are relatively small (Cassirer 1995). In Montana, the long term trend appears downward. Occurrences with larger populations (>5 pairs) appear to be stable over the last 4-8 years, while some small occurrences appear to be declining or have recently gone extinct (see Historic Changes); however, this has not been statistically analyzed. In Wyoming, breeding populations appear stable in Grand Teton National Park (Harlequin Duck Working Group 1993).

POPULATION REGULATION

A simple model using guesstimates for values of survival and fecundity was developed by Goudie and Breault (1994). It estimated that at 85% adult survival, the population would grow at 6%/year. Simulations indicate that the model was most affected by adult survival; an increase of 3% mortality may not be sustainable over the long term (Goudie and Breault 1994).

CONSERVATION AND MANAGEMENT

EFFECTS OF HUMAN ACTIVITY TO HARLEQUIN DUCK POPULATIONS, REPRODUCTION, AND BEHAVIOR

Disturbance on the breeding grounds. *On and near shore*. Kuchel (1977) found that broods less than 4 weeks old avoided areas with human access and selected areas that were distant from access and inaccessible ($p<0.05$) on McDonald Creek in Glacier National Park. This was not true of adults during May and early June when fewer park visitors were present. More recently, Ashley (1994) found Harlequins used inaccessible areas in greater proportion than their availability, though not significantly so; his data is conservative in that surveys took place in the early morning prior to the vast majority of visitor use. Most Harlequins left accessible stream reaches when visitor use reached more than minimal levels. Ashley (1994) found males were displaced by human activity to a greater extent than females. He speculated that this may be due any or all of three reasons. First, females were likely born in Glacier National Park with its many visitors, and are more habituated to humans than males which were likely born at other locations. Second, females spend more time each year, during higher visitation periods, than males on McDonald Creek and may be more habituated to human contact. Third, females are more cryptically colored and less likely to attract casual visitor attention.

On the Rocky Mountain Front in Montana, only 15% of sightings were in areas that were inaccessible (>50 m from established areas of human activity, not accessible by trail) (Diamond and Finnegan 1993). Of the accessible areas, 51% were >50 m from a trail, 21% were 10-50 m from a trail and 13% were <10 m from a trail; it should be noted that >90% of this area is roadless. Visitor use is highest along the South Fork Sun River, where monthly trail use is 500 people in July and August (Diamond and Finnegan 1993).

In Grand Teton National Park, Wyoming, 95% of Harlequin observations were in backcountry areas, accessible only by trail (Wallen 1987). Within the backcountry however, Harlequins used areas with moderate (5-9 people/day) to heavy (>10 people/day) human use more than lesser used areas; Wallen (1987) suggested that may have been the result of the presence of many high

gradient, inaccessible stream reaches which lacked the habitat features Harlequins preferred.

In Yellowstone National Park, a three-year study was done to assess visitor impacts to Harlequin use at LeHardy Rapids where it appeared that duck use had decreased due to high visitor use (McEneaney 1994). The area was closed to visitors from 1 May - 7 June 1991-1993 and Harlequin Duck use increased; a historical nest site in the immediate vicinity was not reoccupied (McEneaney 1994). Beginning in 1995, visitors were to be confined to a boardwalk.

In Idaho, Harlequin Ducks were typically found at sites more than 50 m from road or trail access (adults = 75%, broods = 80%) (Cassirer and Groves 1994). Pair densities there were lowest on streams most accessible to human activity (Cassirer and Groves 1991). In Oregon, duck sightings were much closer to sites with established human activity, with 48% within 10 m (roads 48%, fishing 29%, hiking 19%) (Thompson et al. 1993).

In Washington, a cavity nest with the opening 2.4 m high was located 1.3 from a trail (in 1991) and within a back country corral (1992); the depth of the nest cavity (61 cm) prevent the hen from seeing outside and hid her from view (Cassirer et al. 1993). Two nest cavities in Idaho however, were located in areas seldom used by humans, about 150 m from logging roads (Cassirer et al. 1993).

In Jasper National Park, visitor use by hikers, nature tours, fishermen, tourists, and boaters (see below) on Maligne River drainage has increased substantially in the past decade; during that period Harlequin Duck numbers have also decreased substantially (Clarkson 1992, Hunt 1993). It was felt that disturbance was likely the cause of the decline and recommendations were made to revise the method of controlling rafting including: closing particular river reaches to boating and other human activity; and not issuing new business licences/special activity permits which would increase the current level of human activity in the area (Clarkson 1992).

Within the stream. Cassirer and Groves (1991) reported that 5 of 11 streams where Harlequin breeding was reported or confirmed during 1988-1990 were closed to fishing or did not open to fishing until 1 July.

Wallen (1987) reported that fishing seemed more disruptive to Harlequins than hiking, and they avoided humans on the bank or in the stream bed. Birds would typically swim or dive downstream past people, keeping partially submerged when past and watching behind them as they moved out of the area. Two hens with broods abandoned a section of one creek when fishing pressure increased in August; they moved to a nearby creek which drained into the same lake, and where fishing was not observed (Wallen 1987).

In boats. Prior to significant raft and canoe use on rivers in Jasper and Banff, Holroyd (1979) warned of potential negative effects of intensive river use on Harlequin Ducks. Since that time, commercial white-water rafting on the in Jasper National Park has exposed pre-nesting, and perhaps nesting, ducks to frequent disturbance (Clarkson 1992, Hunt 1993). Only six commercial trips took place there in 1986; commercial use increased to over 1500 trips/year by 1990 (Clarkson1992, Hunt 1993). This was significantly correlated with declining Harlequin Duck numbers during the period 1986-1992 (Hunt 1993). Additionally, the mean monthly abundance of Harlequin Ducks is significantly and negatively correlated with number of rafting trips per month (May, June, July) from 1986-92 (Hunt 1993).

On the Maligne River in 1993, Harlequins were displaced by rafts in 87% of 91 encounters; duck reactions included flying (60%) and swimming (19%) away from the rafts (Clarkson 1992).

Birds usually took flight if a raft was on a collision course with a bird, was within 1-15 m of a bird, or if the raft crew was acting "boisterously" as they passed the duck (Clarkson 1992). Hunt (1993) recommended closure of the river to rafting to attempt to restore historic population levels of Harlequins. He listed other less commercially disruptive actions which could possibly help stem the decline in Harlequins including: 1) reducing the amount of time each day rafting was permitted; 2) reducing the times per day launches were allowed; and 3) reducing the length of the season that river use is permitted (Hunt 1993).

On the Bow River in Banff National Park, reaction to canoes by Harlequins was considerably less (Smith 1996). In 158 encounters, 62.6% of ducks had no reaction, 16.5% swam away, 11.4% flew away, and 9.5% hid (Smith 1996). The considerable difference in reactions between ducks on the Bow and Maligne Rivers is probably due to the fact that the Bow is very much wider and splits in channels in numerous locations (Smith 1996).

Cassirer and Groves (1991) reported that nesting appeared to occur on stream reaches above those used by rafts on the two regularly boated Harlequin Duck streams in Idaho. Heavy white-water rafting is believed to have caused the extirpation of Harlequins on the Methow River in Washington (Brady pers. comm. *in* Clarkson 1994).

Noise. No specific information found.

Collecting and trapping. Collecting permits have been issued in Montana (1), Washington, and Alaska. In Washington, permit for 15 was issued as recently as 1992, with permits for up to 50 issued in previous years (Schirato 1993). There is a market for Harlequins in the avicultural trade, with paris valued at $2,000 or more (C. Pilling, aviculturalist, pers. comm., *in* Harlequin Duck Working Group 1993).

In Iceland, egg collecting was extensively carried out in some areas through the mid-1960s, both for consumption and sale for raising; it is now be prohibited (Bengtson 1972).

Capture of 465 Harlequin Ducks in British Columbia coastal waters resulted in 5 mortalities, 3 by drowning and two by heat prostration (Clarkson and Goudie 1994). In Montana, mist netting over 250 Harlequins on breeding streams has resulted in 1 death by drowning of a duckling and 1 leg injury of an adult.

Shooting. Hunting was the likely cause of the decline of the eastern North American Harlequin Duck population (Philips 1925, Palmer 1949). This was probably because they are less wary than other sea ducks while on the coast (Philips 1925, Palmer 1976) and they forage in shallow water close to shore.

In Alaska, Harlequins are harvested by both recreational and subsistence hunters (Rothe 1994). The extent of hunting in the Pacific North American population appears low, with the exception of a few local areas in Alaska. No band returns from hunting have been reported in over 249 birds banded on breeding areas of Montana, however, a banded bird was found to have holes in the webbing of the foot caused by pellets from a shotgun (Reichel and Genter 1994).

Fishing. Harlequins have been found entangled in fishing line in Glacier National Park on McDonald Creek (Ashley 1994), and in Jasper National Park on Maligne Lake (Clarkson 1992). A Harlequin has also been found with a fish hook lodged in its throat (Cassirer, pers. comm., *in* Clarkson 1992)

Pesticides and other contaminants/toxics. Thousands of Harlequins were killed or injured as a result of the *Exxon Valdez* oil spill of 24 March 1989 (Patten 1993 *in* Clarkson 1994). Later,

productivity in western Prince William Sound, where oil remained, was nearly zero during 1989-1993; reproduction was substantial in un-oiled portions of eastern Prince William Sound (Patten 1994). Petrochemicals were found in the proventriculus, liver and bile in Harlequins in western Prince William Sound and southwestern Kodiak Island; these were probably introduced via feeding on blue mussels (*Mytilus adulis*), an important food of Harlequins (Patten 1994). A relatively small oil spill in 1991 by the *Tenyu Maru* threatened approximately 10% of the Harlequins wintering in Washington (G. Schirato pers. comm. *in* Clarkson 1994). Even the remote western Aleutian Islands, where most Harlequin winter, sparse , but wide-spread oil pollution is a potential threat (Byrd et al. 1992).

Wintering Harlequins concentrate in several areas along the Pacific coast for feeding and molt. Among these concentration areas are the east shore of Vancouver Island where toxic pollutants are abundant (Waldichuk 1983 *in* Clarkson 1994). and commercial, industrial, and recreational development are growing rapidly.

Degradation of habitat: breeding and wintering.

Breeding. In 1992 a gas pipeline project was started, crossing the Moyie River in Idaho 8 times (Cassirer 1995). Harlequins are known to use this stream and a study was begun when siltation was noted from construction. The siltation caused a decline in macroinvertebrates fed on by Harlequins, and there no young were successfully raised the year the construction took place (Cassirer 1995). Recovery of macroinvertebrates was expected to occur within a year and Harlequins successfully bred the following year. The effects of the construction could have been minimized by doing the work in late summer (after 1 September) or fall. The long term effect of the loss of one years production on the very small population present is not known (Cassirer 1995). However, several items were noted, including the fact that Harlequins attempted to breed (unsuccessfully) despite the disturbance, and did not move to nearby streams.

MANAGEMENT

Federal

Fish and Wildlife Service. Neither the Atlantic or Pacific populations are listed as Threatened or Endangered in the United States. The Harlequin Duck was listed as a Category 2 Candidate Species prior to 1996 when that Category was administratively eliminated. It is legally hunted in the Pacific states and provinces under the Migratory Bird Treaty Act and state, provincial and federal regulations. Hunting is closed on the Atlantic flyway.

National Park Service. A seasonal boating closure was instituted on McDonald Creek above Lake McDonald in Glacier National Park in 1995 to protect Harlequin Ducks; the stream is closed to boating from 1 April though 30 September (J. Ashley pers. comm.). No boating on rivers is allowed in Yellowstone National Park to protect wildlife values. No U.S. National Park Service Harlequin Duck management plan exists.

Forest Service. The Harlequin Duck is a Sensitive Species in the Northern, Rocky Mountain, and Pacific Northwest Regions. Forest Service policy states that sensitive species should be managed to ensure that populations do not become threatened or endangered.

States/Heritage Programs. The Harlequin Duck is classified as a state sensitive species in Oregon, a priority habitat species in Washington, and a species of special concern in Idaho and Montana.

Other legal status. The Atlantic population of the Harlequin Duck is listed as Endangered by the Canadian Wildlife Service.

Mitigation procedures. None found.

ONGOING RESEARCH THAT RELATES TO ANY OF THE TOPICS LISTED ABOVE

I. Goudie and C. Smith will begin a banding study in 1996 on the Elbow, Sheep and Highwood Rivers, Alberta, in response to a commercial rafting permit application on the Elbow.

Smith (1995) has begun a multi-year study in 1995 to assess the impacts of upgrading a single-lane Highway to a split double-lane highway beginning in 1996. Banding began in 1995 when 41 adult and 3 ducklings were marked. This site is a very large river compared to Montana Harlequin streams, with perhaps 4 times as many ducks as the largest Montana population (McDonald Creek). Potential impacts on the site include: changes in th natural flow regime, changing in macroinvertebrate food base; increased recreational use; and interruption of stream connectivity by installation of culverts rather than bridges (Smith 1996).

E. F. Cassirer is continuing to survey and monitor Harlequins in Idaho. Currently no marking is taking place. This will add more information about numbers, trends, and productivity.

S. Patton is completing data workup on effects of oil spills in coastal areas on Harlequin Ducks.

I. Goudie and collaborators are continuing to study survival and fidelity to wintering populations in Bristish Columbia. Winter survival and site fidelity are also being studied in Washington (G. Schirato). This data will nicely dovetail with our breeding data to get a complete picture of survival and site fidelity for population modeling.

W. Hunt and P. Clarkson continue to study the effects of rafting on Harlequins in Jasper National Park. They are also banding birds for site fidelity and movement, but have not banded for as many years as we have in Montana nor have they banded many juvinales.

M.E. Brown is begining a master's thesis project which will be a rather fine-grained study of parental kinship and investment, and instances of extrapair fertilizations. Specifically she would like to (1) assess patterns of relatedness of females breeding near one another, which harks to philopatry and the population, genetic, and behavioral consequences thereof; (2) observation on parental behaviors, to address observations of varying brood-abandonment timing and examine parental cost-benefits, etc., and (3) assay broods for extra-parental contribution (either from female egg-dumping or male extra-pair paternity).

D. Esler is working on genetic analysis of North American Pacific coast Harlequin to determine extent of genetic mixing in different winter (primarily) and some summering areas. He hope to determine whether separate Harlequin Duck metapopulations exist within the western North

America region.

PRIORITIES FOR FUTURE RESEARCH

The following are among the highest future research priorities and are primarily a subset of those listed by the Harlequin Duck Working Group (1993) and Cassirer et al. (1996).

1) What are the impacts of human disturbance on breeding and wintering Harlequin Ducks?

Several independent studies have documented the sensitivity of Harlequin Ducks to human disturbance, primarily through the relationship of sighting locations to accessibility of the locations (Kuchel 1977, Wallen 1987, Diamond and Finnegan 1993, Cassirer and Groves 1991, 1994, Clarkson 1992, Ashley 1994). Specifically, boating has been shown to have a significant negative correlation with numbers of ducks present in one area on a medium-sized stream (Clarkson 1992, Hunt 1993). Observations in other areas tend to support this conclusion (Cassirer and Groves 1991, Brady pers. comm. *in* Clarkson 1992) in this may not be the case in very large streams (Smith 1996). Fishing and human presence has also been suggested as a cause of disturbance with specific examples, but without statistical data analyses (Wallen 1987, McEneaney 1994, Cassirer and Groves 1991).

Wide-scale analyses have not yet been attempted nor have analyses on the effects of most specific kinds and amounts of human activities except boating. Several specifics should be done to address these questions.

First, wide-scale data on Harlequin streams should be gathered including productivity, population size, length of stream segments used during pair and brood seasons, categories and locations of land ownership of the streams, hydrogeological properties of the streams, habitat of the streams, and current human use of the stream (by roads, trails, structures, activity, etc.). A first step will be to see what is available and what needs to be gathered in the field. Some such as population size, and length of stream segments used is known for many streams, while others need preliminary data gathering to determine what is available (hydrogeological properties, habitat of the streams, and current human use). We can then randomly select unused and/or unknown streams that fit physical parameters of used streams and compare them in respect to kind and amounts of disturbance/accessibility. See Proposals 2 and 3.

Second, responses to humans could be evaluated by recording initial responses to surveyors. This would only give immediate, in sight response of birds which were seen; presumably some would react prior to the surveyor seeing them and not be observed. Nor would it revel how much time or distance the bird moved in reaction to the disturbance. A more precise but intrusive method would be to use radiotelemetry on the birds. Radio-telemetry would also provide more accurate data on use of habitat types and locations relative to human development/access points. See Proposal 4.

Third, if actions are undertaken on Harlequin streams, they should be monitored to determine there effects. This allows us to learn the effects of various actions and not repeat mistakes in the future. To determine effects of specific land management or development actions on Harlequin streams, the action should be proceeded by at least two years of baseline marking and surveying for population size and productivity, habitat evaluation, and pre-action levels of human activity and development. The population should be monitored during and following the action to determine the effects of the action. Actions which particularly need attention include road, campsite, and trail construction and upgrading, including any increased accessibility and changes in human use of the area; actions which could result in changes to flow regimes or water quality, such as mining, road building, timber harvest, industrial development, and water/hydroelectric development; changes in fishing regulations which could change fishing use of the area; building of structures such as industrial areas, dams, or houses which will increase the access and use of a Harlequin stream. Possibilities for mitigation and habitat restoration can be explored during these projects.

2) What is the extent and nature of movements in breeding and wintering areas?

This information is needed to determine the possibilities for naturally recolonizing new and historic Harlequin occurrences; naturally supplementing existing occurrences, particularly small populations; and how strong natal and adult fidelity to particular sites are. All these are needed to successfully model Harlequin populations and their stability, with both breeding and wintering grounds data incorporated.

Radio-telemetry may give quick results from the standpoint of local daily movements, however, I expect that long distance (>5 km) movements are relatively rare and with limited numbers of ducks radioed may not be best for long distance movement detection. For long distance and moves between years, visibly marking birds is best. For association to natal areas, this will be a long term project, but Montana has the best start with 250 birds banded on the breeding grounds since 1992. With the start we have now, I estimate sufficient information for preliminary modeling will be available following the 1996 field season if funding is received, and good information could be available following the 1998 field season for final modeling.

For the wintering grounds, much data is available and is currently being collected in Washington, Alaska, and British Columbia. It should be available within 2 years with sufficient information to use in detailed population modeling. For an accurate model, information is necessary from both the breeding and wintering grounds. See Proposals 1, 4, 5.

3) Are distinct metapopulations (such as a Rocky Mountain breeding population) identifiable within the Pacific range of the Harlequin Duck?

The degree of genetic differences among and within wintering and breeding subpopulations would allow an assessment of the appropriate management units for various Harlequin conservation strategies. Dan Esler, Alaska National Biological Service is currently examining this question, primarily for wintering areas, but he is also examining blood samples we are providing from

Montana.

4) What are the critical habitat components limiting Harlequin Duck breeding and wintering populations?

Harlequin Ducks use a wide variety of habitats on the breeding grounds, from forests to tundra. Habitat usage should be documented over a large number of study areas to identify common habitat components and compare them to available habitat; there are both large and small scale considerations here. See Proposals 2, 3, 4.

5) How and why do productivity and survival change over time and among areas, and what are the relative impacts of these changes on populations?

Long term studies are needed to determine population parameters and then incorporate them into population models (with information from movements on the breeding and wintering grounds). These parameters include: productivity; age-related survival; recruitment; age(s) at first breeding and/or successful breeding; age(s) last breeding; life expectancy; and causes and timing of mortality. These can only be done with long-term studies involving marked birds on both the breeding and wintering area. Currently we are in a good position to complete these studies given that we already have 4 years of data and coastal populations are currently being marked and studies. See Proposal 1.

The most difficult question is the causes of mortality, which is not tractable given current technology. If and when small, long range mortality transmitters are available for ducks, this should be pursued.

6) What are the characteristics of Harlequin Duck migration? How well defined are migratory staging areas and migration corridors?

This question may not be tractable given current technology. If and when small, long range mortality transmitters are available for ducks, this should be pursued. Some answers may come from large scale marking of individuals such as in Proposal 1, and perhaps by relocating radioed birds in Proposal 4.

RESEARCH PROPOSALS TO ADDRESS THE MOST CRITICAL DATA GAPS

List of Attached Proposals

1. Harlequin Duck Population Parameters, Site Fidelity, and Movements
2. Review of Hydrologic and Geologic Data Availability for Harlequin Duck Breeding Streams in Montana.
3. Large scale evaluation of characteristics of occupied versus unoccupied Harlequin Duck streams in Montana.

4. Radio-telemetry study of the effects of disturbance on movements and habitat selection by Harlequin Ducks.
5. Site fidelity, productivity, survival, and recruitment of Harlequin Ducks in western North America: Modeling the available data.

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