



Harlequin Duck (*Histrionicus histrionicus*) Occurrence and Habitat Selection in North Cascades National Park Service Complex, Washington

Natural Resource Report NPS/NOCA/NRR—2022/2370





ON THIS PAGE

A female harlequin duck foraging in the Stehekin River, North Cascades National Park Service Complex, WA. 2016.
NPS / JASON RANSOM

ON THE COVER

A breeding pair of harlequin ducks on the Stehekin River, North Cascades National Park Service Complex, WA. 2017.
NPS / JASON RANSOM

Harlequin Duck (*Histrionicus histrionicus*) Occurrence and Habitat Selection in North Cascades National Park Service Complex, Washington

Natural Resource Report NPS/NOCA/NRR—2022/2370

Kristin M. Rine, Roger G. Christophersen, and Jason I. Ransom

National Park Service
North Cascades National Park Service Complex
810 State Route 20
Sedro-Woolley, WA 98284

April 2022

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible and technically accurate.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Rine, K. M., R. G. Christophersen, and J. I. Ransom. 2022. Harlequin duck (*Histrionicus histrionicus*) occurrence and habitat selection in North Cascades National Park Service Complex, Washington. Natural Resource Report NPS/NOCA/NRR—2022/2370. National Park Service, Fort Collins, Colorado. <https://doi.org/10.36967/nrr-2293127>.

Contents

	Page
Figures.....	iv
Tables.....	v
Appendices.....	vii
Executive Summary	viii
Acknowledgments.....	x
Introduction.....	1
Study Area	4
Methods.....	6
Occupancy and productivity surveys.....	6
Data analysis.....	10
Harlequin duck observations	10
Breeding chronology	10
Habitat characteristics	11
Results.....	12
Survey and incidental observations	12
Breeding chronology	15
Geographic distribution	16
Habitat associations	18
Discussion.....	23
Survey and incidental observations	23
Breeding chronology	23
Geographic distribution	24
Habitat associations	25
Data Improvements	28
Current and Emerging Threats.....	30
Literature Cited	33

Figures

	Page
Figure 1. Annual harlequin duck population estimates (number of birds) with 90% confidence intervals for all Salish Sea wintering areas in Washington State.	3
Figure 2. Location of the North Cascades National Park Service Complex in Washington State (North Cascades National Park, Ross Lake National Recreation Area, and Lake Chelan National Recreation Area), as part of the North Cascades Ecosystem.	4
Figure 3. North Cascades National Park Service Complex streams surveyed for harlequin ducks for 15 years between 1990 and 2017.	7
Figure 4. Distribution of brood sizes observed incidentally and during surveys ($n = 39$) in North Cascades National Park Service Complex between 1990 and 2021.	14
Figure 5. Annual totals of incidental harlequin duck observations ($n = 184$) in North Cascades National Park Service Complex recorded between 1968 and 2021.	15
Figure 6. Detection phenology of harlequin ducks across North Cascades National Park Service Complex streams for various demographic groups (pairs, $n = 135$; unpaired males, $n = 81$; unpaired females, $n = 96$; and broods, $n = 39$).	16
Figure 7. Geographic distribution of harlequin duck observations made in North Cascades National Park Service Complex incidentally and during active stream surveys (reach extents are highlighted in yellow).	17
Figure 8. Distribution of elevations at North Cascades National Park Service Complex harlequin duck observations sites by demographic group (pairs, $n = 40$; unpaired males, $n = 27$; unpaired females, $n = 35$; and broods, $n = 23$).	18
Figure C-1. Image of data sheet used by North Cascades National Park Service Complex staff for observations of harlequin ducks during formal surveys, 1990–2017.	51

Tables

	Page
Table 1. Summary of landform, stream, and basin characteristics for harlequin duck survey stream reaches in North Cascades National Park Service Complex.	8
Table 2. Dates of harlequin duck surveys in North Cascades National Park Service Complex from 1990 through 2017.....	9
Table 3. Summary of surveys and harlequin ducks observed in North Cascades National Park Service Complex study reaches, 1990–2017.....	12
Table 4. Composition of instream habitat parameters ($n = 156$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	19
Table 5. Composition of stream substrate parameters ($n = 186$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	19
Table 6. Composition of channel morphology parameters ($n = 187$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	19
Table 7. Composition of streambank composition parameters ($n = 139$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	19
Table 8. Composition of riparian overstory parameters ($n = 138$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	19
Table 9. Composition of presence of one or more woody debris features ($n = 61$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	20
Table 10. Composition of presence of stream channel features ($n = 115$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	20
Table 11. Composition of human access parameters ($n = 1855$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	20
Table 12. Composition of instream habitat parameters ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	21

Tables (continued)

	Page
Table 13. Composition of stream substrate parameters ($n = 25$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	21
Table 14. Composition of channel morphology parameters ($n = 25$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	21
Table 15. Composition of streambank composition parameters ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	21
Table 16. Composition of riparian overstory parameters ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	21
Table 17. Composition of instream presence of stream channel features ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	22
Table 18. Composition of human access parameters ($n = 25$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017.....	22
Table A-1. Summary of stream reaches surveyed by North Cascades National Park Service Complex staff (1990–2017).	39
Table A-2. Distribution of observations dates for harlequin duck demographic groups. Data represent all harlequin duck observations (surveyed and incidental) in North Cascades National Park Service Complex from 1968–2021.	39
Table A-3. Distribution of observation site elevations for harlequin duck demographic groups.....	40
Table A-4. Habitat parameters and their definitions used in evaluating sites of harlequin duck observations in North Cascades National Park Service Complex streams during surveys (1990–2017).....	40
Table B-1. Observations of harlequin ducks and associated species made during occupancy and productivity surveys in North Cascades National Park Service Complex streams (1990–2017).....	42
Table B-2. Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$).	44

Appendices

	Page
Appendix A. Harlequin duck survey details and habitat parameters	39
Appendix B. Harlequin duck and associated species observations	42
Appendix C. Data sheet for harlequin duck surveys.....	51

Executive Summary

Harlequin ducks (*Histrionicus histrionicus*) are sea ducks that migrate inland each spring to nest along fast-flowing mountain streams. They are considered one of the most imperiled duck species in North America and occur in two distinct populations on the Atlantic and Pacific coasts. The Pacific coast population includes Washington State, where harlequin ducks breed in the Olympic, Cascade, and Selkirk Mountains. This species is designated as a Management Priority species by the National Park Service within North Cascades National Park Service Complex (NOCA). This report summarizes harlequin duck surveys conducted during 15 years across a 27-year period (1990 and 2017) on major streams within NOCA, and incidental observations collected from 1968–2021. The primary objectives of these surveys were to 1) document the distribution and abundance of harlequin duck observations within NOCA boundaries, 2) describe productivity (number of broods and brood size), 3) describe breeding chronology of harlequin ducks, and 4) describe habitat characteristics of breeding streams.

Sixty-eight stream surveys over 15 years resulted in observations of 623 individual harlequin ducks comprising various demographics, including single adults, pairs, and broods. In addition, we collected 184 incidental observations of harlequin ducks from visitors and staff between 1968–2021. Harlequin ducks were observed on 22 separate second- to sixth-order streams throughout NOCA across the entire 53-year span of data, both incidentally and during harlequin duck surveys by Park staff. Harlequin ducks were detected on 8 of the 13 streams that were actively surveyed. Excluding recounts, 88.7% ($n = 330$) of individual harlequin duck observations during surveys occurred in the Stehekin River drainage. Between all surveys and incidental observations, 135 unpaired females without broods were sighted across all NOCA waterways. Thirty-nine broods were recorded between NOCA surveys and incidental observations, with a mean brood size of $3.61 (\pm 1.44 \text{ SD}; \text{range} = 2\text{--}10)$. Breeding pairs were recorded as early as April 5 and were seen on streams until June 15, a period of less than seven weeks (median: May 2), but most pairs were observed within a 3-week span, between April 26 and May 17. Single females (unpaired with a male, with (an)other female(s), or with a brood) were observed on streams between April 26 and August 25 (median: July 3), though most observations were made within a 5-week period between June 12 and July 19.

Habitat data collected at adult harlequin duck observation sites indicate that the birds often used stream reaches with features that are characteristic of high-energy running water. While adults occupied all instream habitat types identified, non-braided rapids and riffles were used most frequently, followed by pools and backwaters. Larger instream substrate sizes (cobbles and boulders) were present at most observation sites. Adult harlequin ducks were more often found at locations that lacked visible drifting or lodged woody debris, but drift debris was a slightly more abundant debris type. The presence of gravel bars and at least one loafing site was common. Adult harlequin ducks were more often observed in association with vegetation that offered some cover over the channel, but not where banks were undercut. The average channel width at adult observation sites was 34.0 m (range: 6–80 m; $n = 114$) and 27.6 m ($\pm 15.7 \text{ m}$; range: 10–60 m; $n = 12$) at brood observation sites.

Compared to adult harlequin duck sites, broods were observed more frequently in low velocity habitat (pools, backwaters), but rarely in rapids. Cobble and boulder substrates were still the most dominant substrate type. Contrary to adult ducks, broods were observed most often observed in meandering stream channels, a morphology indicative of low gradient, low velocity stream reaches. Most broods were observed in stream reaches with gravel bars, loafing sites, and overhanging vegetation, but were rarely seen in channels with undercut banks. There also appeared to be frequent use of reaches with mature and old-growth trees, but similar to adult locations, shrubs were relatively less common. Over half of all harlequin duck observations were over 50 m away from human activity regardless of accessibility, while it was uncommon to see broods less than 10 m away.

While it is not possible to infer abundance or population trends using the data collected to date, these data have provided important information on persistent occupancy of some streams within NOCA, and habitat characteristics that harlequin ducks have selected for during the breeding season. Current and emerging threats to this species may include increase and timing of aquatic and riparian recreation, bioaccumulation of environmental contaminants, and features of climate change such as warming water temperatures and flow regimes. Channel or streambank alterations for land management purposes can also negatively affect habitat suitability if they prevent recruitment of large woody debris used for nesting, cover, and loafing sites, and if they reduce instream habitat complexity. As higher trophic consumers, harlequin ducks are especially vulnerable to environmental contaminants such as heavy metals, polychlorinated biphenyls (PCBs), and microplastics. Monitoring these contaminants in lower trophic levels, such as benthic invertebrates, amphibians, and fish, will contribute to harlequin duck conservation. The impacts of Skagit River impoundment features (i.e., reservoirs, dams) on harlequin duck migration and broader ecology, are currently unknown.

NOCA and other National Parks in Washington represent near-pristine harlequin duck breeding habitat and continue to serve as refugia in the region. Future monitoring of breeding streams across public land units in the region should be based on standardized objectives and protocols to more effectively evaluate population trends, threats, and effects of different land management policies. Unified monitoring efforts would allow deeper data inference and more holistic conservation of harlequin ducks across the North Cascades Ecosystem.

Acknowledgments

This work was conducted in the traditional homelands of the Confederated Tribes of the Colville Reservation, Lummi Tribe, Nlaka'pamux Nation, Nooksack Indian Tribe, Sauk-Suiattle Indian Tribe, Stillaguamish Tribe of Indians, Sto:lo Nation, Swinomish Indian Tribal Community, Upper Skagit Indian Tribe, and Yakama Nation. Many individuals were instrumental in collecting these data. Thank you to North Cascades National Park Service Complex staff, field technicians, and former wildlife biologist R. Kuntz, who assisted in collecting and curating the historical harlequin duck survey and observational data for the Park Complex. Special thanks to M. Holmgren and Institute for Bird Populations staff for diligently recording harlequin duck observations during landbird fieldwork. Thank you to M. Hamer, M. Holmgren, and R. Wolstenholme for constructive reviews of this report. Funding for this project was provided by the National Park Service.

Introduction

Harlequin ducks (*Histrionicus histrionicus*) are small sea ducks that migrate inland each spring to breed and nest along fast-flowing mountain streams, often returning to the same drainage in successive breeding seasons (Bengston 1972, Cassirer and Groves 1994). Breeding males are slate blue with chestnut flanks and crown, and have white patches and spots on their head, neck, and back, while immature and nonbreeding males lack several of these distinct markings against their slate blue bodies. Females are an inconspicuous dusky brown with three white spots on the sides of their head. Younger juveniles are similar in appearance to females but have yellowish-legs and feet, whereas the legs and feet of adults are completely gray (Robertson and Goudie 1999). Males are approximately 10 percent larger than females. Harlequin ducks are divers that, in their freshwater breeding habitat, navigate fast-flowing, turbulent water, to forage mainly on benthic aquatic insects (Robertson and Goudie 1999, Wright et al. 2000).

Disjunct populations of harlequin ducks inhabit the Pacific and Atlantic Coasts. While these populations appear isolated, no subspecies are currently recognized. The Pacific population can be found in western North America from Oregon to Alaska along western coastal habitats during wintering seasons, breeding inland along the same latitudinal range as far east as Montana and Wyoming. The Pacific population can also be found along eastern Asia. The Atlantic population breeds in eastern Canada, Iceland, and southern Greenland, wintering along the coast of Iceland, southern Greenland, and from southeastern Canada through New England (Robertson and Goudie 1999). Washington populations can be found in the Olympic, Cascade, and Selkirk Mountains. Historically, populations were observed in the Blue Mountains (Schirato 1994), and while there have been several recent eBird reports of pairs in this area (eBird Basic Dataset 2021), the status of this breeding population is unknown.

The harlequin duck is considered one of the most imperiled ducks in North America, although the global population is currently listed as a *Species of Least Concern* by the International Union for the Conservation of Nature (IUCN 2019). Breeding populations are considered to be *Critically Imperiled* and *Imperiled* in the contiguous United States, although *Apparently Secure* in Alaska (NatureServe 2019). This species received relatively little scientific attention before the listing of the Atlantic Canadian population as endangered in 1990. That particular population is designated as a *Species of Special Concern*, with additional provincial listings as either *Endangered* or *Vulnerable* (COSEWIC 2013). The listing in Canada spurred investigations into protections for the US Pacific and Atlantic populations in the early 1990s, yet federal protection or candidacy under the Endangered Species Act has not been established. The harlequin duck is not listed in Washington State (WDFW 2019) but is considered a *Species of Greatest Conservation Need* in the Washington State Wildlife Action Plan (WDFW 2015). Breeding populations in Oregon and Washington are designated as *Sensitive* by the Interagency Special Status/Sensitive Species Program (ISSSSP). Within North Cascades National Park Service Complex (hereafter, NOCA or Park Complex), this species is designated by the National Park Service as a *Management Priority* species.

The Atlantic population (estimated between 3,226 and 3,420 individuals) has experienced a drastic decline since the 1800s, primarily in response to hunting and habitat degradation, but it appears that the population has stabilized since the cessation of hunting in 1990 (USFWS 1998, COSEWIC 2013). Estimates for the Pacific population have historically been comparatively robust (estimated between 150,000 and 1 million individuals); however, abundance is greatest in the coastal waters of Alaska, and decreases with latitude (USFWS 1998, Sea Duck Joint Venture 2015). Based on Christmas Bird Count data from the National Audubon Society (National Audubon Society 2002) in coastal Oregon and Washington, there has been an overall increase in population since 1951 and little population change since the mid-1980s (Rockwell 2018). Reasons for declines in harlequin duck populations are not well understood nor have they been directly measured. However, potential key impacts include hunting (Robertson and Goudie 1999), contaminants/toxics (Piatt et al. 1990, Fischer 1998), habitat loss or degradation (Breault and Savard 1991, Freeman and Goudie 1998), human disturbance to nesting ducks (Kuchel 1977, Wallen 1987, Cassirer and Groves 1989, Hunt 1998), and increased disturbances and resource limitations driven by climate change (Harper and Peckarsky 2006, Royan et al. 2014, Hansen et al. 2019).

Based on the most recent aerial surveys of wintering seabirds in the U.S. portion of the Salish Sea, Washington Department of Fish and Wildlife (WDFW) estimated a total population size of 4,722 (90% CI: 4204–5216) harlequin ducks in 2020 and an average of 4,750 harlequin ducks between 1999 and 2020 (Figure 1, WDFW unpublished data). Surveys during this 20-year period showed an overall stable population trend (Figure 1), but with greater variability across different Salish Sea basins (WDFW 2021). Because data on breeding grounds are lacking, population estimates of wintering birds may be a better gauge of overall population trends in the Pacific Northwest.

Even after an uptick in ecological studies since the 1990s, there is much to learn about certain breeding populations of harlequin ducks, most notably those in Washington where information is especially scarce (Rockwell 2018). Most studies concerning the Pacific population have been conducted in the intermountain west (e.g., Kuchel 1977, Wallen 1987, Cassirer and Groves 1989, Smith 1996, Hansen 2014, MacCallum et al. 2016) and British Columbia (e.g., Robertson 1997, Machmer 2001, Bond et al. 2008, LeBourdais et al. 2009), as well as a few studies from the Oregon Cascades (Bruner 1997, Wright et al. 2000). Knowledge of harlequin ducks in Washington is primarily sourced from nearly 30 years (1994 to present) of aerial counts on wintering grounds to measure population trends (WDFW 2021), yet only a few studies from breeding grounds exist (Farrell 1997, Blackie 2002, Singleton and Long 2018).

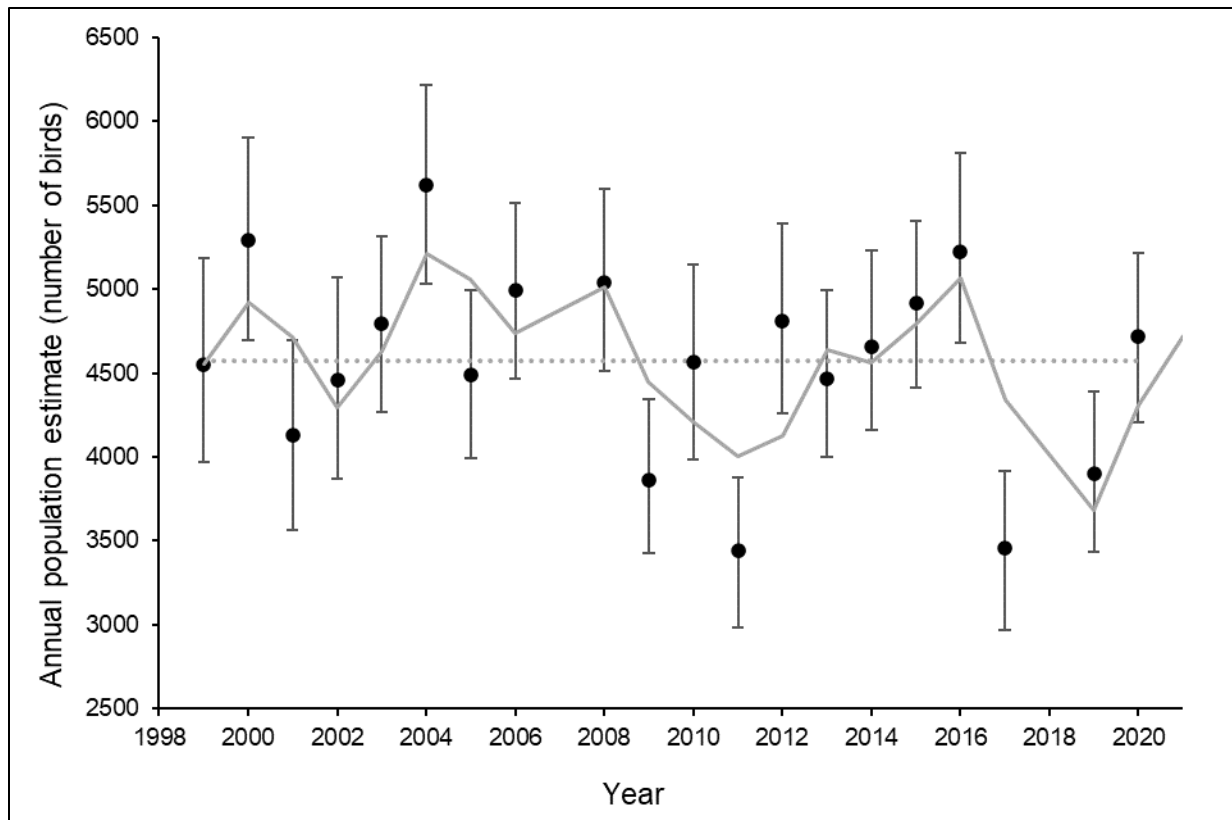


Figure 1. Annual harlequin duck population estimates (number of birds) with 90% confidence intervals for all Salish Sea wintering areas in Washington State. The solid gray line represents an estimate of the interannual population trend and the horizontal dashed line shows the average number of birds detected during this period. Data were collected as a part of the WDFW midwinter aerial seabird surveys. Model-generated estimates and confidence intervals were provided by WDFW biologists to be used in this plot. These data are accessible at: <https://wdfw.wa.gov/species-habitats/at-risk/species-recovery/seabirds/surveys-winter-aerial>.

This report summarizes harlequin duck surveys conducted between 1990 and 2017 on major streams within NOCA. The primary objectives of these surveys included 1) documenting the distribution and abundance of harlequin duck observations within NOCA boundaries, 2) describing productivity (number of broods and brood size), 3) describing breeding chronology of harlequin ducks, and 4) describing habitat characteristics at sites where harlequins were observed. We simultaneously collected data on presence and distribution on four associated species that share breeding habitat along the same fast-flowing mountain streams used by harlequin ducks: common merganser (*Mergus merganser*), spotted sandpiper (*Actitis macularia*), belted kingfisher (*Ceryle alcyon*), and American dipper (*Cinclus mexicanus*) (see Appendix B, Table B-1).

Study Area

North Cascades National Park Service Complex is comprised of North Cascades National Park, Ross Lake National Recreation Area (ROLA), and Lake Chelan National Recreation Area (LACH), and is located in north-central Washington (Figure 2). These NPS-managed lands consist of mostly roadless wilderness, except for one highway bisecting the Park Complex. Within NOCA, 93% of the land is designated as the Stephen Mather Wilderness. The majority of land surrounding NOCA is U.S. Forest Service-managed land consisting of the Mount Baker-Snoqualmie National Forest, Wenatchee National Forest, and Okanogan National Forest, which includes the Mount Baker Wilderness, Glacier Peak Wilderness, Lake Chelan-Sawtooth Wilderness, Noisy-Diobsud Wilderness, and Pasayten Wilderness.

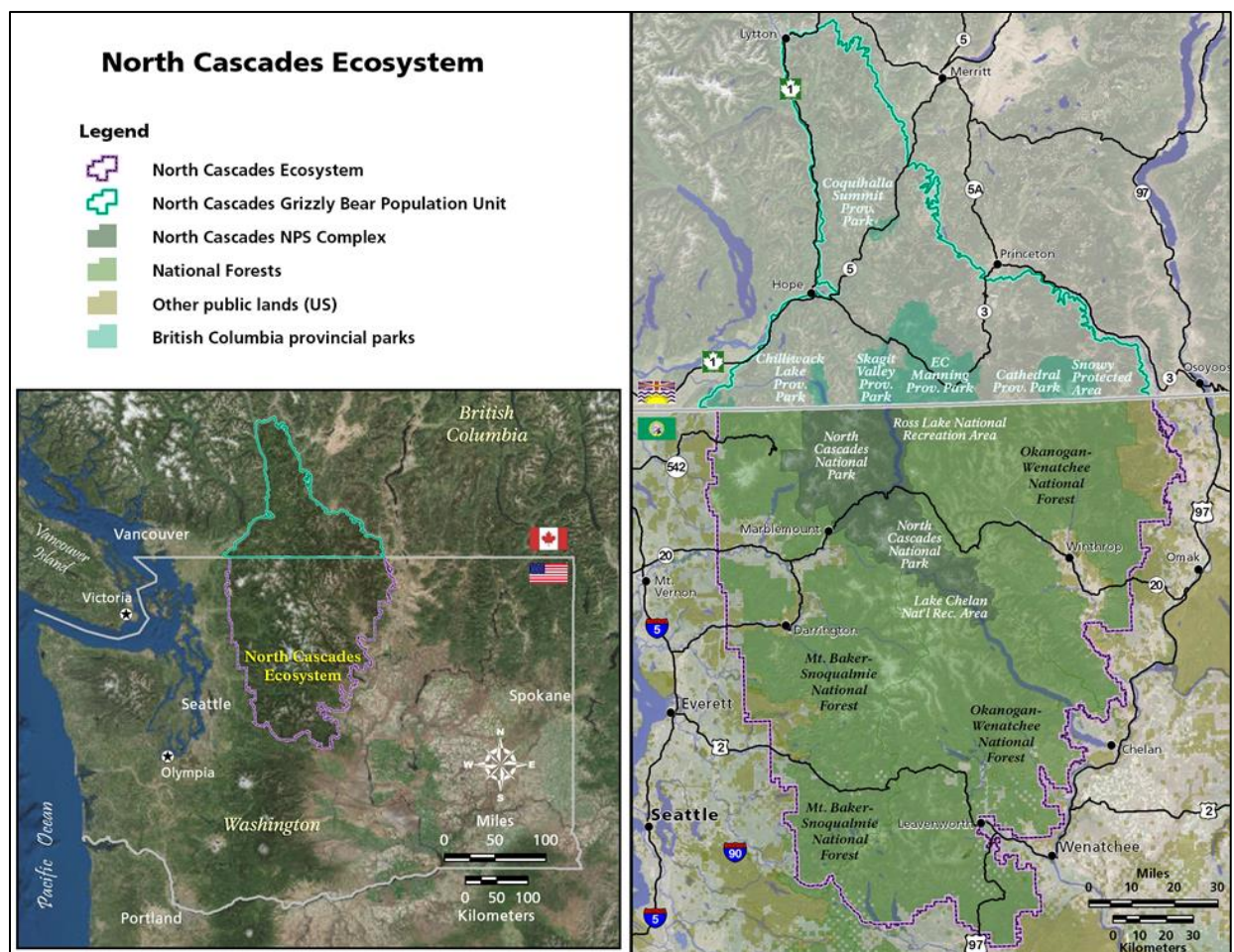


Figure 2. Location of the North Cascades National Park Service Complex in Washington State (North Cascades National Park, Ross Lake National Recreation Area, and Lake Chelan National Recreation Area), as part of the North Cascades Ecosystem.

The Park Complex includes lands from low elevation forested valleys (119 m) to high elevation glaciated mountain peaks (2,806 m), encompassing a total of 276,815 ha. Spanning the crest of the

Cascade Range, the Park Complex lies within two major biogeographic zones: the temperate marine west of the Cascade crest and semi-arid continental east of the Cascade crest (Franklin and Dyrness 1973). This orographic divide affects weather patterns, with the highest amounts of precipitation occurring to the west of the Cascade crest (>500 cm annually), and the least amounts to the east of the crest with <50 cm annually (Mote 2003). Because of the divide and the wide range in elevation and precipitation, the Park Complex contains a number of life zones (Pojar and MacKinnon 1994). The Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) zone is located at river valleys <600 m. The Pacific silver fir (*Abies amabilis*) zone exists in mountain forests at elevations of 600 m to 1700 m. The subalpine zone is located in mountain meadows at elevations between 1200 m and 2100 m, while the alpine zone exists at elevations >2100 m (Pojar and MacKinnon 1994). Excluding intermittent streams, there are approximately 3,225 kilometers of rivers and streams in the Park Complex (Rawhouser et al. 2009).

Methods

Occupancy and productivity surveys

We chose 13 streams in NOCA to survey for harlequin duck use (Figure 3). We based selection of streams to survey for harlequin ducks on definitions of suitable stream habitat and stream morphology used by harlequin ducks in Idaho (Cassirer and Groves 1994), in Grand Teton National Park in Wyoming (Wallen 1987), and in Montana (Kuchel 1977). Streams were also chosen based on previous incidental sightings of harlequin ducks (NOCA Wildlife Observation Database). All streams surveyed were classified as third order or higher (S. Zyskowski, NPS pers. comm.). In general, target characteristics of streams selected for this survey included 1) stream sections that include swift-moving water used early in the breeding season, interspersed with slower-moving stretches needed during brood-rearing, 2) stream gradients less than 5%, 3) minimum channel width of 10 meters, 4) substrates classified as cobble and boulder, 5) in-stream rocks or logs that protrude from water and can be used as loafing sites, 6) over-hanging vegetation along most stream banks, 7) adjacent overstory vegetation classified as mature or old-growth (Table 1).

Survey reach start and end points were predetermined for each stream and were used consistently for all survey attempts (Appendix A, Table A-1). Survey reach lengths for different streams ranged between 5.4 and 30.1 km, making up between 22.8 and 84.9% of total stream lengths (Appendix A, Table A-1). Surveys were only completed within the NOCA boundary, which served as the downstream starting point for some streams (Bacon Creek, Baker River, Chilliwack River, and North Fork Cascade River) that flow out of the Park Complex (Figure 3).

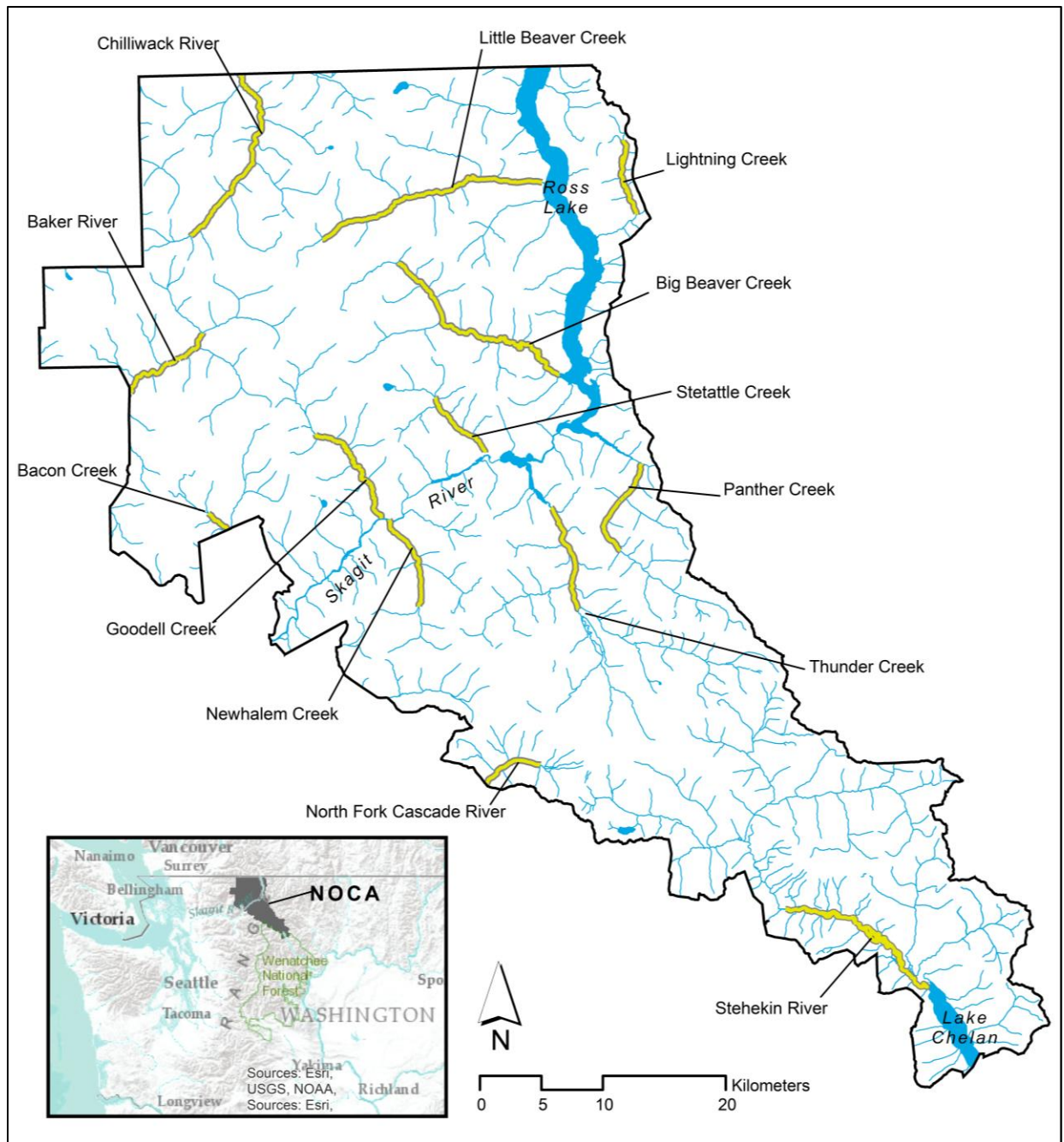


Figure 3. North Cascades National Park Service Complex streams surveyed for harlequin ducks for 15 years between 1990 and 2017. Survey reaches are highlighted in yellow.

Table 1. Summary of landform, stream, and basin characteristics for harlequin duck survey stream reaches in North Cascades National Park Service Complex.

Drainage	Area ^a	% Glacial ^b	Mean % Gradient ^b	Mean % Canopy ^b	Stream Order ^b	Elevation (m)		
						Basin Max	Basin Min	Survey Mean ^b
Bacon Creek	131.0	0.0	4.1	71.4	3	2211.3	117.7	418.5
Baker River	184.4	4.0	1.6	46.2	3	2775.5	254.4	331.7
Big Beaver Creek	164.8	3.0	1.6	75.5	4	2528.5	491.1	595.3
Cascade River, NF	57.1	5.0	4.3	83.1	3	2679.2	469.4	638.3
Chilliwack River	138.8	1.0	1.3	69.3	4	2711.5	634.4	712.8
Goodell Creek	100.7	3.0	2.9	65.0	4	2531.5	144.9	284.9
Lightning Creek	89.8	0.0	1.8	85.5	4	2513.2	570.4	621.3
Little Beaver Creek	139.4	5.0	1.7	83.5	4	2726.7	491.1	664.0
Newhalem Creek	72.3	1.0	3.6	84.1	3	2473.6	205.6	472.0
Panther Creek	94.9	3.0	4.5	88.6	4	2653.5	512.4	747.6
Stehekin River	885.0	3.0	0.8	17.8	6	2857.9	335.5	401.8
Stetattle Creek	59.1	2.0	4.4	75.0	3	2247.9	269.3	419.6
Thunder Creek	280.4	13.0	3.2	84.1	4	2763.3	369.1	485.9
Average (±SD)	164.2 (205.4)	3.2 (3.4)	2.8 (1.7)	73.25 (18.5)	3.8 (0.8)	2414.5 (670.8)	347.4 (186.8)	532.8 (141.5)

^a Calculated as the drainage area (m²) upstream from the bottom of the survey reach.

^b Calculated as the mean value of the survey reach based on GIS data.

We attempted to conduct two surveys on each suitable harlequin duck breeding stream. The first (occupancy) surveys were conducted between late April and late May when pairs were thought to be arriving on established breeding territories. Productivity surveys were conducted from early July through mid-August when broods are most visible and water levels from spring runoff had begun to recede. Occasionally, logistical limitations prevented productivity surveys from occurring within the same year as an occupancy survey (e.g., Baker River; Table 2). Survey effort varied by year, depending on resources available, access, and environmental conditions. The greatest effort occurred between 1990 and 1994 on the Stehekin River, where multiple surveys were completed within the breeding and brood-rearing seasons. Multiple surveys were sometimes completed on the same reach within a span of several days (e.g., 4/23/1993 and 4/26/1993, Stehekin River).

Table 2. Dates of harlequin duck surveys in North Cascades National Park Service Complex from 1990 through 2017.

Drainage	Year	Survey Date	
		Occupancy	Productivity
Bacon Creek	1999	May 11	Jul 19
Baker River	1999	May 12–13	Not surveyed
Big Beaver Creek	2001	May 8–9	Jul 17–18
Cascade River, NF	2000	May 10–11	Jul 20
Chilliwack River	2000	May 22	Jul 21
	2016	Jun 1	Not surveyed
Goodell Creek	1998	May 11–12	Jul 6–8
Lightning Creek	2002	May 17	Jul 17
Little Beaver Creek	2001	May 22	Jul 16–18
	2016	May 23–24	Not surveyed
Newhalem Creek	1997	May 27–28	Jul 16–17
	2015	May 28	Not surveyed
	2016	May 10–11	Not surveyed
Panther Creek	1998	May 19–21	Jul 9
Stehekin River	1990	May 17, Jun 12*	Jul 2*, 3; Aug 7*; Sep 6*
	1991	Apr 26, May 14*, May 28*, Jun 13*	Jul 2, Jul 24*, Aug 13*, Sep 10*
	1993	Apr 23*, 26; May 20*, 24*; Jun 17*	Jul 1, Aug 13*
	1994	Apr 27, May 25*, Jun 13*	Jul 19, Sep 1*
	1995	Apr 22	Jul 25
	1996	May 18	Jul 11
	1997	May 17, Jun 10*	Jul 8
	1998	May 2	Jul 17
	1999	May 21	Jul 17
	2000	May 17	Not surveyed
	2015	Not surveyed	Jul 28
	2016	May 4-5	Jul 13
	2017	May 11	Not surveyed
Stetattle Creek	1998	May 12–13	Jun 30
Thunder Creek	2002	May 21–25	Jul 23–25
	2016	May 17	Not surveyed

*Survey data not used for demographic analysis to control for recounts of individuals

Survey methods were based largely on those employed by other harlequin duck studies conducted in the western United States (Kuchel 1977, Wallen 1987, Cassirer and Groves 1989). During both occupancy and productivity surveys, visual searches were conducted by two people walking upstream along the bank or wading directly in the channel, stopping frequently to scan upriver and

into side-channel habitat using binoculars with 8X to 10X magnification. In addition, several Stehekin River surveys in the 1990s were conducted by a team of 3–4 observers floating the river in a raft. An observation is defined as a sighting of at least one individual, but may also include multiple individuals (e.g., one female and her brood). Geographic coordinates (UTM) of harlequin duck and associated species locations were recorded either at the time of observation using a handheld GPS device or estimated upon returning from the field using topographic maps or GIS software (either ArcMap or Caltopo.com).

We classified all harlequin ducks by life stage (adult, young) and sex, when possible. We used the term “brood” to classify ducklings that were hatched within the season and typically seen in broods, but we did not attempt to identify age classes of ducklings. Associated species demographics were generally not specified unless the age and sex were visually distinctive; but in most cases, these demographic parameters were recorded as unknown (Appendix B, Table B-1).

At locations where one or more harlequin ducks were observed, habitat parameters (listed and defined in Appendix Table A-4) were recorded. Stream width was estimated visually or using a laser range finder (e.g., Sig Sauer, model Kilo850). Some records lack much of the possible information about the habitat characteristics present where harlequin ducks were observed. Habitat parameters were not recorded when only associated bird species were seen, or when Park visitors or other staff reported an incidental (non-surveyed) harlequin duck observation.

Data analysis

Heterogeneous survey efforts and methods, detectability of harlequin ducks, and recording of habitat parameters limited the statistical techniques and inferences that could be applied to this dataset. While future efforts may focus on standardizing these variables in order to evaluate distribution and abundance of harlequin ducks within NOCA, inferences from this report are based on basic summaries of raw data (e.g., relative proportions, raw counts and totals). Given that we are not performing statistical tests on the data, that outlying observations are present, and that observational distributions are highly variable, we report median values rather than mean values.

Harlequin duck observations

A summary of original raw count data from field surveys is presented in Appendix B, Table B-1. We based simple demographic summaries on only one occupancy and one productivity survey per year and stream to control the possibility of counting the same individual twice. Only the event with the highest overall count of harlequin ducks was used when more than one survey of the same type (occupancy vs. productivity) was completed within the same reach and year (Table 2).

Breeding chronology

To evaluate timing of breeding activities on NOCA streams, we plotted the distribution of observation dates for various demographics (pairs, unpaired males, unpaired females, and broods), grouping data from all NOCA streams, years, and observation types. To control the possibility of recounting individuals, we used data from only one occupancy and one productivity survey per year and stream, each with the greatest number of observations. In addition, we excluded incidental observations made on the same stream within the same month as the survey. Analysis of timing for

unpaired females is based on those individuals observed without broods in order to distinguish successfully reproducing females (seen with broods) from others that may have foregone breeding, feeding off a nest, or when their clutch has failed.

Habitat characteristics

We summarized habitat features and measurements recorded at adult and brood observation sites separately. Habitat features (e.g., rapids, pools) are expressed as relative abundance, or percentage, of all features within a habitat parameter (e.g., instream habitat). Habitat parameters recorded in the first year of surveys, 1990, used several metrics that differed from those collected in subsequent years. In order to preserve interannual and geographic comparability, these metrics were excluded from habitat summaries. Data used in habitat summaries included possible recount events as well as observations where only a subset of parameters were recorded, in order to include the full breadth of habitat associations.

Results

Survey and incidental observations

Sixty-eight stream surveys over 15 years resulted in observations of 623 individual harlequin ducks comprising various demographics (Table 3; Appendix Table B-1). Excluding potential intra-annual recounts (see methods section) resulted in 51 surveys and 372 individuals over the same time period. Some of the females sighted in occupancy surveys were likely recounted during follow-up productivity surveys completed within the same year, after leaving nests with their broods. Spotted sandpiper was the most frequently detected associated species, ($n = 197$), followed by common merganser ($n = 135$), American dipper ($n = 139$) and belted kingfisher ($n = 22$) (Appendix B, Table B-1).

Table 3. Summary of surveys and harlequin ducks observed in North Cascades National Park Service Complex study reaches, 1990–2017. OCC = Occupancy survey; PRO = Productivity survey. Dashes = no observations (not applicable to Baker River productivity survey, which was not attempted).

Drainage	Survey Type	No Surveys	Unpaired Males	Unpaired Females	Pairs	No. Broods	Total Individuals
Bacon Creek	OCC	1	–	–	–	–	0
	PRO	1	–	–	–	–	0
Baker River	OCC	1	–	2	1	–	4
	PRO ^a	–	–	–	–	–	–
Big Beaver Creek	OCC	1	1	–	1	–	3
	PRO	1	–	1	–	–	1
NF Cascade River	OCC	1	–	–	–	–	0
	PRO	1	–	–	–	–	0
Chilliwack River	OCC	2	–	1	–	–	1
	PRO	1	–	2	–	1	5
Goodell Creek	OCC	1	1	–	–	–	1
	PRO	1	–	–	–	–	0
Lightning Creek	OCC	1	–	–	–	–	0
	PRO	1	–	–	–	–	0
Little Beaver Creek	OCC	2	–	1	1	–	3
	PRO	1	–	2	–	2	8
Newhalem Creek	OCC	3	1	–	2	–	5
	PRO	1	–	3	–	1	5

^a No surveys completed.

^b Values without parentheses represent interannual totals using only the highest count values from one survey type per year. These values were used in demographic summaries to exclude potential recounted individuals.

^c Values in parentheses represent cumulative counts for all surveys completed, which include multiple surveys per survey type within one year. These higher values likely reflect some recounts of multiple individuals.

Table 3 (continued). Summary of surveys and harlequin ducks observed in North Cascades National Park Service Complex study reaches, 1990–2017. OCC = Occupancy survey; PRO = Productivity survey. Dashes = no observations (not applicable to Baker River productivity survey, which was not attempted).

Drainage	Survey Type	No Surveys	Unpaired Males	Unpaired Females	Pairs	No. Broods	Total Individuals
Panther Creek	OCC	1	–	–	–	–	0
	PRO	1	–	–	–	–	0
Stehekin River	OCC	13 ^b (23) ^c	51 (94)	14 (51)	82 (127)	0 (3)	232 (419)
	PRO	10 (17)	1 (1)	51 (84)	1 (1)	13 (22)	98 (162)
Stetattle Creek	OCC	1	–	–	–	–	0
	PRO	1	–	–	–	–	0
Thunder Creek	OCC	2	2	–	2	–	6
	PRO	1	–	1	–	–	1
Totals	–	51 (68)	57 (100)	78 (148)	90 (135)	17 (29)	372 (623)

^a No surveys completed.

^b Values without parentheses represent interannual totals using only the highest count values from one survey type per year. These values were used in demographic summaries to exclude potential recounted individuals.

^c Values in parentheses represent cumulative counts for all surveys completed, which include multiple surveys per survey type within one year. These higher values likely reflect some recounts of multiple individuals.

Excluding recounts, 88.7% ($n = 330$) of individual harlequin duck observations during surveys occurred on the Stehekin River (Tables 2 and 3). The number of individuals on Little Beaver Creek ($n = 11$), Newhalem Creek ($n = 10$), Thunder Creek ($n = 7$), Chilliwack River ($n = 5$), Baker River ($n = 4$), Big Beaver Creek ($n = 4$), and Goodell Creek ($n = 1$) accounted for the remaining 11.3% ($n = 42$) of individuals recorded (Table 3). Surveys on the Stehekin River accounted for the highest instantaneous counts of all demographics: pairs ($n = 16$ on 4/26/1993), broods ($n = 4$ on 7/2/1990 and 7/17/1998), single males ($n = 6$ on 5/18/1996 and 5/21/1999), and single females ($n = 7$ on 7/3/1990 and 7/1/1993).

Between all surveys and incidental observations, 135 unpaired females without broods were sighted across all NOCA waterways. A small portion of observations ($n = 17$) making up this total consisted of groups of 2–3 females together, or occasionally a group with a male. Fewer unpaired males were observed ($n = 102$). Most sightings ($n = 58$) consisted of lone males, while groups of 2 or more males ($n = 11$; range: 2 to 4) or groups with one or more females ($n = 12$; data not shown) were less common.

Thirty-nine broods were recorded between NOCA surveys and incidental observations, with a mean brood size of $3.61 (\pm 1.44 \text{ SD}; \text{Range: } 2\text{--}10; \text{Figure } 4)$. Excluding recounts, 17 broods were detected during active surveys over the study period. Most of these detections occurred on the Stehekin River ($n = 13$), while others occurred on the Chilliwack River ($n = 1$), Little Beaver Creek ($n = 2$), and Newhalem Creek ($n = 1$; Table 3). Incidental sightings of broods also occurred in the Stehekin River ($n = 18$), Chilliwack River ($n = 2$), Goodell Creek ($n = 1$), and Thunder Creek ($n = 2$; Appendix B, Table B-2).

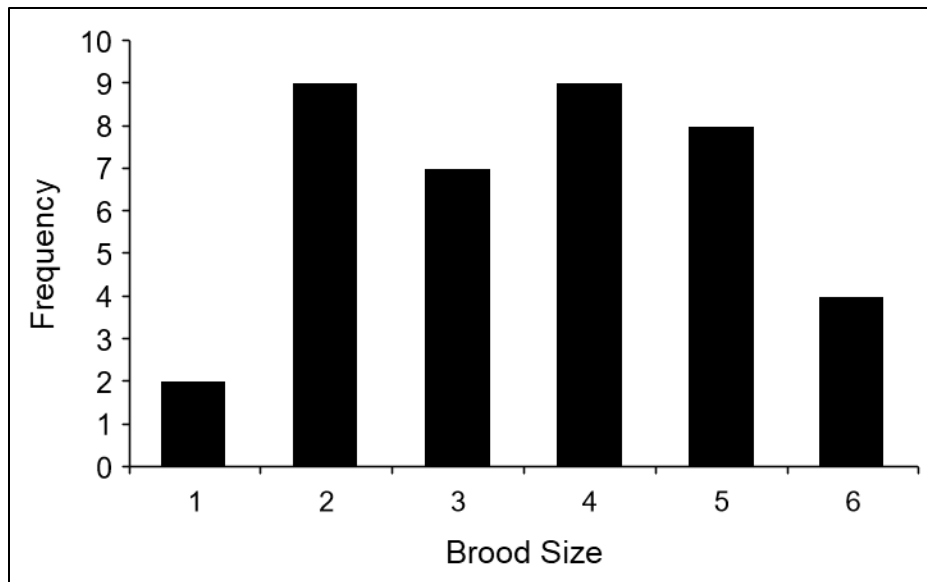


Figure 4. Distribution of brood sizes observed incidentally and during surveys ($n = 39$) in North Cascades National Park Service Complex between 1990 and 2021.

Between 1968 and 2021, 184 incidental observations of harlequin ducks were made by Park staff and visitors (Appendix B, Table B-2). The greatest proportion of sightings were made on the Stehekin River ($n = 87$, 47.3%), followed by Thunder Creek ($n = 35$, 19.0%), the mainstem Skagit River and its reservoirs ($n = 24$, 13.0%), and Goodell Creek ($n = 10$, 5.4%; Appendix B, Table B-2). From the establishment of record-keeping in 1968 through the mid-1980s, only one to two observations per year were recorded (Figure 5). Beginning in 1984, annual observation reports began to increase and peaked in 1989 ($n = 15$), generally remaining elevated through 2000, but with high variability (range: 3–15; Figure 5). No observations were recorded between 2005 and 2011. No interannual trend was apparent from these data (Figure 5).

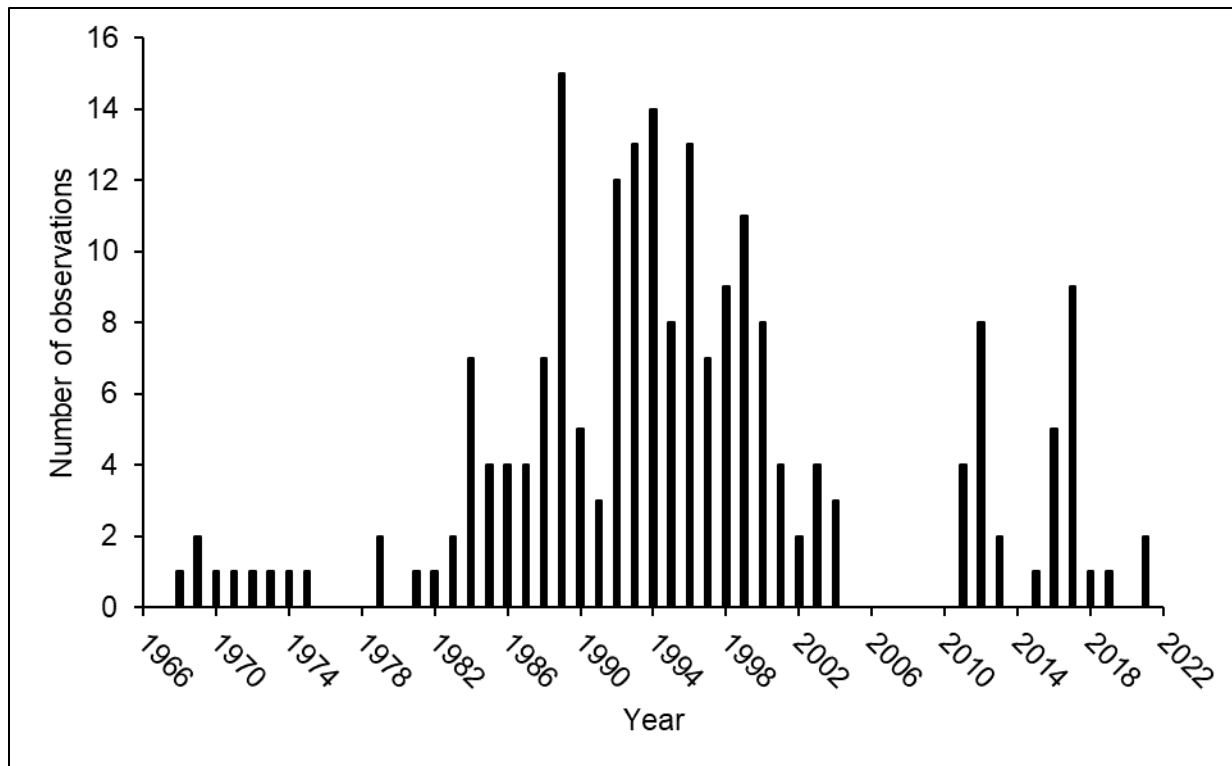


Figure 5. Annual totals of incidental harlequin duck observations ($n = 184$) in North Cascades National Park Service Complex recorded between 1968 and 2021.

Breeding chronology

The earliest seasonal harlequin duck observation on record was an incidental sighting of a single male on the mainstem Stehekin River on March 24 (Figure 6, Appendix Table A-2). The range of observations for unpaired males on breeding streams throughout NOCA spanned 15 weeks until June 30 (median: May 17), however there were several outliers that were observed through early November. Most unpaired males were observed within a 4-week period, from April 26 to May 26.

Breeding pairs were recorded as early as April 5 and were seen on streams until June 15, a period of less than seven weeks (median: May 2), but most pairs were observed within a 3-week span, between April 26 and May 17 (Appendix Table A-2). Two outlying observations of pairs occurred in early July and mid-August. Single females (unpaired with a male, with (an)other female(s), or with a brood) were observed on streams between April 26 and August 25 (median: July 3), though most observations were made within a 5-week period between June 12 and July 19. Outlying observations were made early in the season on April 5 and late in the season on September 21 and October 2. Broods were observed within a much shorter timeframe between June 14 and August 5, and most observations occurred between July 3 and July 20 (median: July 12; Figure 6, Appendix A, Table A-2).

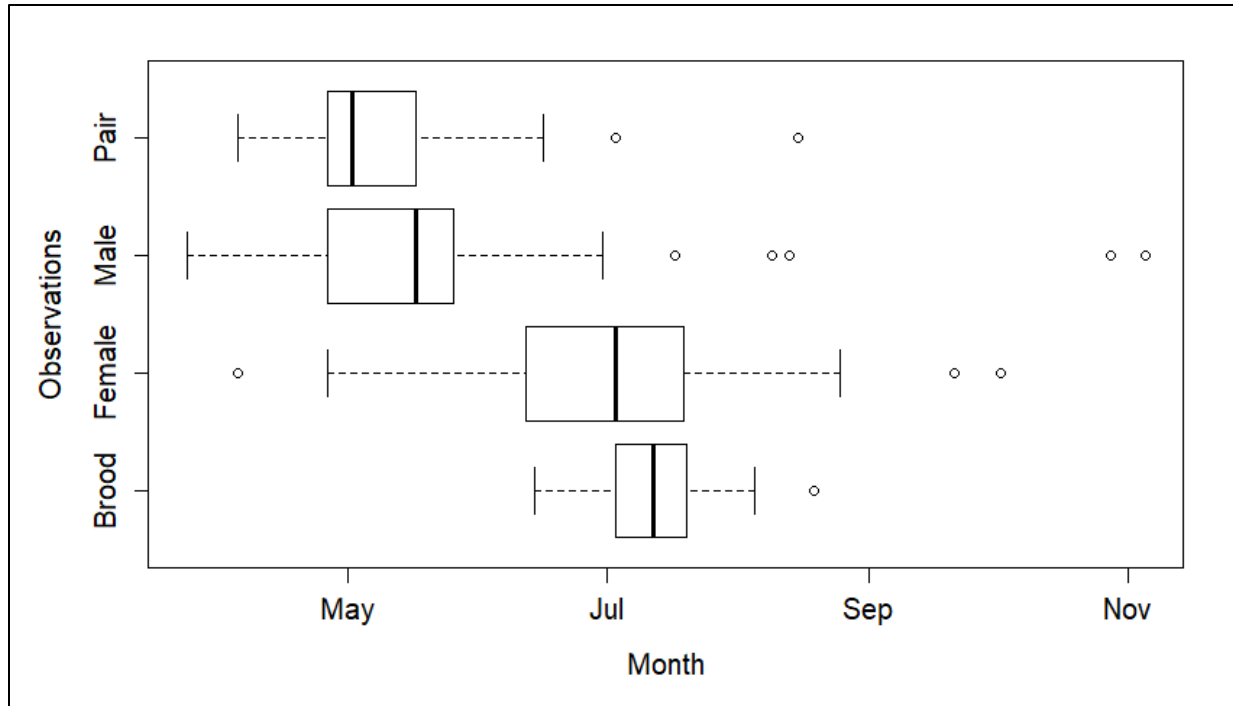


Figure 6. Detection phenology of harlequin ducks across North Cascades National Park Service Complex streams for various demographic groups (pairs, $n = 135$; unpaired males, $n = 81$; unpaired females, $n = 96$; and broods, $n = 39$). Data include both active surveys by NPS staff and incidental observations (1968–2021). Unpaired females were those observed without broods.

Geographic distribution

Harlequin ducks were observed on 22 separate second to sixth order streams throughout NOCA between 1968 and 2021, both incidentally and during harlequin duck surveys by Park staff. Harlequin ducks were detected on 8 of the 13 streams that were actively surveyed (Table 3, Figure 7). They were not observed during surveys in the Bacon Creek, Lightning Creek, Panther Creek, Stetattle Creek, and North Fork Cascade River drainages. Incidental sightings have occurred on each of these streams except for Stetattle and Lightning Creeks. Incidental sightings were made on six second to fourth order streams that were not surveyed: Hozomeen, Ladder, West Fork Thunder, Fisher, North Fork Bridge, and mainstem Bridge Creeks (Figure 7). Incidental sightings also occurred along the mainstem Skagit River, Ross Lake and Diablo Lake reservoirs, and in reaches of streams outside of the Park boundary (not shown in map).

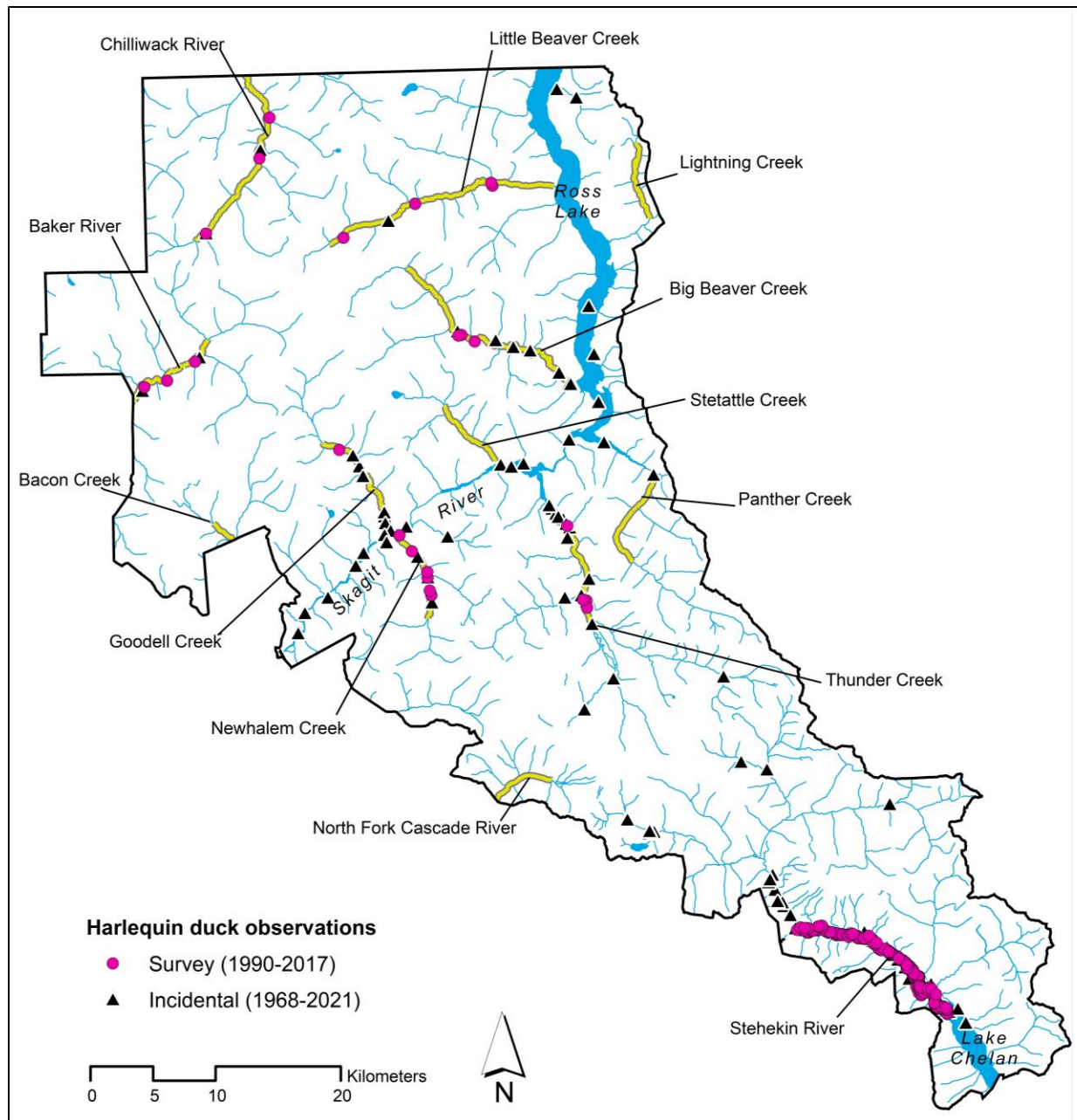


Figure 7. Geographic distribution of harlequin duck observations made in North Cascades National Park Service Complex incidentally and during active stream surveys (reach extents are highlighted in yellow). Harlequin ducks were confirmed on lower reaches of Bacon Creek, the North Fork Cascade River and Baker River that fall outside of Park boundaries (not shown on map), 1990–2017.

Incidental and survey observations were not confined to lower reaches of breeding streams, but instead were generally found all throughout drainage basins with the exception of first order tributaries (e.g., Chilliwack River, Little Beaver Creek, Stehekin River; Figure 7). The elevation of sightings ranged from 85 to 1192 m, with a median elevation of 371.0 m (± 220.5 m; Figure 8, Appendix A, Table A-3). Unpaired males and pairs were observed on relatively low elevation stream

reaches, generally under 600 m (medians at 362 m and 361 m, respectively), while unpaired female detections occurred up to 960 m (median: 425.0 m). Females with broods were sighted at the highest elevations of any demographic group, to nearly 1200 m (median: 361 m, Figure 8, Appendix A, Table A-3).

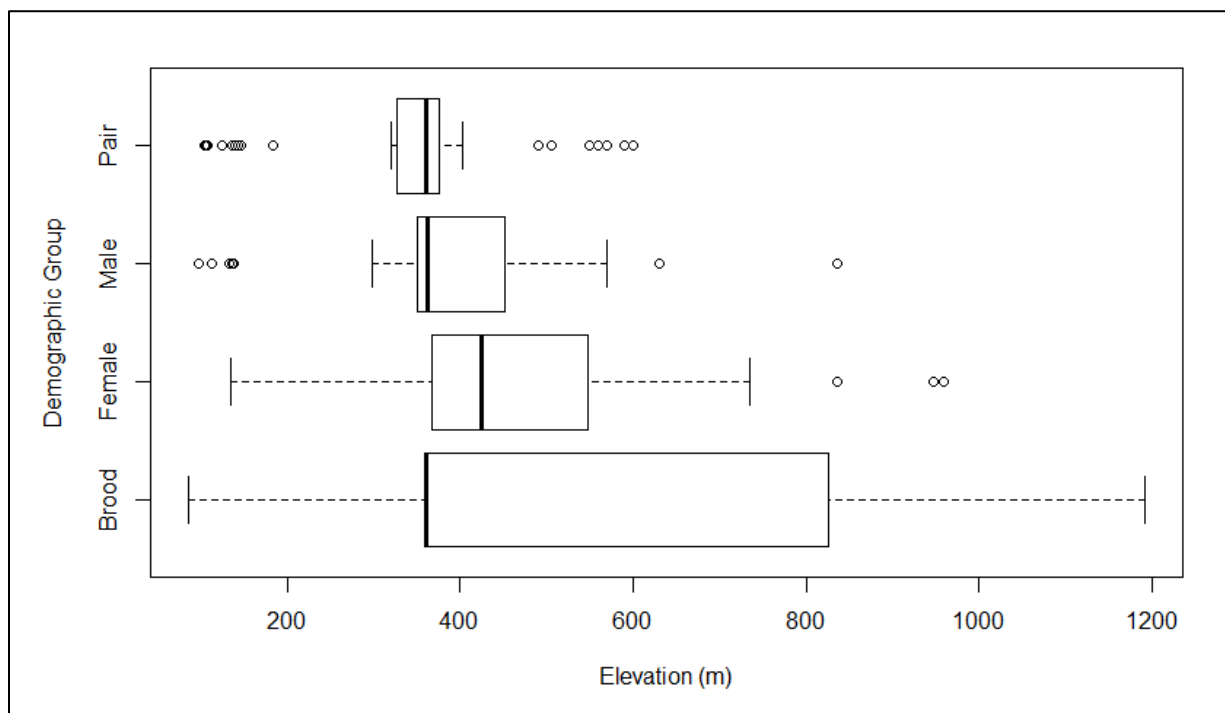


Figure 8. Distribution of elevations at North Cascades National Park Service Complex harlequin duck observations sites by demographic group (pairs, $n = 40$; unpaired males, $n = 27$; unpaired females, $n = 35$; and broods, $n = 23$). Data include both active surveys by NPS staff and verified incidental observations (1968–2021). Unpaired females were those observed without broods.

Habitat associations

Most adult harlequin duck observations where habitat data were recorded ($n = 269$; 93.1%) represent locations within the Stehekin River survey reach. The remaining habitat data were recorded in the Newhalem Creek ($n = 5$; 1.7%), Thunder Creek ($n = 4$; 1.4%), Baker River ($n = 3$; 1.0%), Big Beaver Creek ($n = 3$; 1.0%), Chilliwack River ($n = 2$; 0.7%), Little Beaver Creek ($n = 2$; 0.7%), and Goodell Creek ($n = 1$; 0.3%) survey reaches. Similarly, the majority of brood habitat data were observed from the Stehekin River ($n = 25$; 86.2%), while a relatively small number came from Little Beaver Creek ($n = 2$; 6.9%), Newhalem Creek ($n = 1$; 3.4%), and Chilliwack River ($n = 1$; 3.4%) survey reaches.

Habitat data collected at adult harlequin duck observation sites show that instream features characteristic of high-energy running water are generally important. While adults occupied all instream habitat types identified, non-braided rapids and riffles were used the most frequently, followed by pools and backwaters (Tables 4 through 11). Larger instream substrate sizes (cobbles and boulders) were identified at most observation sites. They were more often found at locations that

lacked visible drifting or lodged woody debris (ramps and bridges), but drift was a slightly more abundant debris type. The presence of gravel bars and at least one loafing site was common. Harlequin ducks were more often observed in association with vegetation that offered some cover over the channel, but not where banks were undercut (Tables 4 through 11). The average channel width at adult observation sites was 34.0 m ($\pm$ 16.8 m; range: 6–80 m; n = 114).

Table 4. Composition of instream habitat parameters (n = 156) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Rapid	Riffle	Pool	Backwater	Glide	Run	PWc
% of total	47.4	20.5	14.7	5.8	4.5	3.8	3.2

*PW = pocketwater.

Table 5. Composition of stream substrate parameters (n = 186) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Cobble	Boulder	Sand	Gravel	Mud	Bedrock
% of total	53.8	41.4	3.8	1.1	0.0	0.0

Table 6. Composition of channel morphology parameters (n = 187) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Straight	Curved	Meander	Braided
% of total	38.0	35.8	15.0	11.2

Table 7. Composition of streambank composition parameters (n = 139) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Trees	G/C/B*	Shrubs	Debris	Forbs	Silt/sand
% of total	70.3	16.4	9.4	2.4	1.0	0.3

*G/C/B = gravel/cobble/boulder.

Table 8. Composition of riparian overstory parameters (n = 138) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Mature	Young	Old-growth	Shrub
% of total	55.6	33.9	6.3	4.2

Table 9. Composition of presence of one or more woody debris features ($n = 61$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Drift	Ramp	Bridge	Collapsed bridge
% of total	29.7	26.0	7.8	3.2

Table 10. Composition of presence of stream channel features ($n = 115$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Loafing site	Veg OH*	Gravel bar	Island	Cut bank
% of total	75.7	71.8	62.4	31.5	17.4

*Veg OH = overhanging vegetation.

Table 11. Composition of human access parameters ($n = 1855$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Accessible	Inaccessible	Near	Adjacent
% of total	35.7	24.9	22.7	16.8

Mature forest was the dominant overstory type where adult harlequin ducks were observed during surveys. Both mature and young trees were significant riparian features, while old-growth forest was rarely associated. Over 60% of adult observations were made in areas relatively removed (over 50 m away) from human disturbance, but it does not appear important whether the observation sites were connected by a trail. Observations of adults were only occasionally made at locations less than 10 m from human activity (Tables 4 through 11; Appendix A, Table A-4).

Compared to adult harlequin duck sites, broods were observed more frequently in low velocity habitat (pools, backwaters), but rarely in rapids (Tables 12 through 18). Cobble and boulder substrates were still the most dominant substrate type. Contrary to adults, broods were most often observed in meandering stream channels, a morphology indicative of low gradient, low velocity stream reaches. Most broods were observed in stream reaches with gravel bars, loafing sites, and overhanging vegetation, but were rarely seen in channels with undercut banks. Only four brood observations from surveys recorded data on the presence of woody debris types; therefore, these data are not presented in Tables 12 through 18.

Mature and old-growth trees were the most dominant streambank and overstory types where broods were observed, and similar to adult locations, shrubs were relatively less common. This vegetation was hanging over the channels at most sites. Over half of all brood observations were over 50 m away from human activity regardless of accessibility, while it was uncommon to see broods less than

10 m away. The average channel width at brood observation sites was 27.6 m (± 15.7 m; range: 10–60 m; $n = 12$).

Table 12. Composition of instream habitat parameters ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Riffle	Pool	Glide	Backwater	Rapid	Run	PW*
% of total	33.3	25.0	25.0	8.3	8.3	0.0	0.0

*PW = pocketwater.

Table 13. Composition of stream substrate parameters ($n = 25$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Cobble	Boulder	Gravel	Sand	Mud	Bedrock
% of total	44.0	44.0	12.0	0.0	0.0	0.0

Table 14. Composition of channel morphology parameters ($n = 25$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Meander	Straight	Braided	Curved
% of total	52.0	20.0	16.0	12.0

Table 15. Composition of streambank composition parameters ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Trees	Shrubs	G/C/B*	Debris	Forbs	Silt/sand
% of total	69.6	13.0	8.7	4.3	0.0	0.0

*G/C/B = gravel/cobble/boulder.

Table 16 Composition of riparian overstory parameters ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Mature	Old-growth	Young	Shrub
% of total	50.0	25.0	16.7	8.3

Table 17. Composition of instream presence of stream channel features ($n = 12$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Gravel bar	Veg OH*	Loafing site	Island	Cut bank
% of total	75	66.7	60.9	50	16.7

*Veg OH = overhanging vegetation.

Table 18. Composition of human access parameters ($n = 25$) recorded at adult harlequin duck observation sites in North Cascades National Park Service Complex, 1990–2017. Detailed definitions of habitat parameters are listed in Appendix A, Table A-4.

Metric	Near	Inaccessible	Accessible	Adjacent
% of total	32.0	28.0	28.0	12.0

Discussion

Survey and incidental observations

Survey effort was extensive given the remoteness of the target stream reaches, but was highly variable across time and space. Most survey reaches are accessible by trail but are typically only visible for a fraction of their total lengths. In strong contrast, much of the 17-km Stehekin River survey reach is continuously visible from its banks and at many points along a main road that supports daily residential and visitor traffic. The majority of incidental observations in this watershed only extend as far upstream as this road, illustrating what is likely a detection bias. For this reason, we are not able to estimate parkwide abundance or densities. Regardless, the Stehekin drainage probably supports the highest abundance and densities simply due to its large watershed area and varied aquatic habitats.

The mean observed brood size (3.61 ducklings, $n = 39$) was similar to other reported values of brood size at fledging, although brood size is highly dependent on duckling age. Bruner (1997) estimated that most duckling mortalities occur during the first two weeks after hatching. Because over 76% (30 of 39) of all brood observations occurred on the lower section of the Stehekin River, we expect that these observations represent the ducklings remaining after early-phase mortality events. No productivity data are currently published for Washington, though other published mean values for brood sizes at fledging in western North America range from 2.4 in Alaska (Crowley 1999) to 3.9 in Montana (Kuchell 1977).

Breeding chronology

Across all years, the first seasonal observations of harlequin ducks recorded on NOCA streams were unpaired males in late March (incidental observations). This group preceded the arrival of pairs by approximately two weeks, aligning with Kuchel's (1977) observations in Glacier National Park. It is common for there to be an excess of males on breeding streams early in the season (Bengston 1972, Cassirer and Groves 1989) despite the propensity of harlequin ducks to migrate in pairs that were formed on wintering grounds (Robertson and Goudie 1999, Smith et al. 2000). Unpaired males, either alone or in groups, that were observed before nest initiation (May through early-June) may be younger non-breeding bachelors or breeding males (at least 2–3 years; Robertson et al. 1998) that failed to pair on wintering grounds: both of these groups are known to maintain fidelity to breeding streams (Kuchel 1977, Smith et al. 2000). Very few observations of males on NOCA waterways have been made after the end of June, as they are known to return to wintering grounds shortly after females begin incubation (Robertson 1997). Pairs began arriving on NOCA streams in early April, similar to populations observed in the Oregon Cascades (Wright et al. 2000). Although males were the first demographic group to be observed, the median date of observation (May 17) occurred after that of pairs (May 2), which probably reflects the tendency for males to remain on streams after mating.

Given that most broods on NOCA streams were observed between July 3 and July 20, most hatching likely occurred from late May to mid-June, with egg laying in late April to early May, assuming a 28-day incubation period (Bengston 1972). Ducklings were not aged during surveys by NOCA staff,

so egg laying and hatching dates cannot be reliably estimated, but similar timing has been observed for populations in the Oregon Cascades and Upper Skagit River of southern British Columbia (hatching late-May through late-June; Bruner 1997, Wright et al. 2000, Freeman and Goudie 2001). There are only four known nest observations in the Washington Cascades between 1920 (Taylor and Shaw 1927) and 2018 (Morris et al. 2018), occurring in Mount Rainier National Park and adjacent Gifford Pinchot National Forest. Dates of observation spanned from May 23 through June 28. Only one of these nests (Morris et al. 2018, Mount Rainier National Park) was recorded in detail from the time it was found on May 27 until the ducklings left the nest on June 21 (a period of 25 days).

Females without mates or broods were observed throughout most of the breeding season (generally until the end of August), either alone or with other females. Robertson (1997) also observed that groups of females typically left breeding streams by the end of August. These individuals may have foregone breeding that year, been separated from mates, been away from nests to feed, or experienced clutch loss (Bengston 1972, Robertson 1997, Wright et al. 2000). The proportion of non-breeding females on streams can be substantial (8 to 62%; Dzinbal 1982, Wallen 1987, Crowley 1994, Bruner 1997, Bond et al. 2008), depending in large part on food abundance (Bengston and Ulfstrand 1971, Robertson and Goudie 1999). Primary factors dictating departure date variability on breeding grounds is not well understood, but is likely related to the phenological timing and abundance of benthic invertebrate prey (Dzinbal 1982, Wright et al. 2000, Blackie 2002).

Geographic distribution

Harlequin ducks are widely distributed across NOCA drainages. Apparent distribution is likely affected by variations in both geographic and temporal survey effort as well as the visibility of suitable habitat by observers. Only a relatively small number of incidental sightings occurred on six streams that were not surveyed by NOCA staff. This may indicate that the original selection of survey streams was a good representation of preferred breeding streams in the Park Complex with some degree of human access and observer visibility. Stetattle and Lightning Creeks were the only notable drainages where harlequin ducks were not observed either incidentally or during surveys. The upper reaches of Stetattle and Lightning Creeks were surveyed by wading directly in the stream channels or by walking along the banks, but each of these streams was surveyed once across the entire study period, making detections much less likely.

Harlequin duck detections were not confined to lower reaches of NOCA drainages, but rather were found near and downstream of headwaters on reaches classified as second-order or higher. Females and broods were observed at higher elevations than pairs and males, but the median elevation for brood observations (361 m, elevation at Harlequin Bridge on the Stehekin River) was similar to pairs and males. This pattern suggests that after mating in lower reaches of drainages, at least some females migrate further upstream for nesting and brood rearing, though it is not evident that females exclusively use lower order tributaries (higher elevations) for these purposes. Studies from other western breeding populations indicate that these life history decisions affecting distribution are flexible, depending on specific drainage and habitat characteristics. Harlequin ducks in the Oregon Cascades showed a similar differential use of drainages (Bruner 1997). However, on the southern

coast of Alaska, all radio-tagged females chose nest locations in first-order tributaries (Crowley 1994).

Occupancy modeling using USFS data from Washington revealed that elevation was one of the most effective landscape-scale characteristics for distinguishing breeding reaches in the Cascades, with most (66%) detections occurring at moderate elevations (between 461 m and 1011 m; Singleton and Long 2018). Stream gradient was the other important predictor, where probability of detection was highest on reaches with a gentle gradient (<5%; Singleton and Long 2018). Other studies on Pacific populations agree that gradient is one of the most important landscape-scale predictors of occupancy. Harlequin ducks in the Upper Skagit River (British Columbia, Canada) were not observed on streams with gradients less than 1% and those greater than 7% (Freeman and Goudie 2001), while the breeding populations on the Salmo River (southeastern British Columbia, Canada) and Priest River (northern Idaho) used stream reaches under approximately 3% (Machmer 2001 and Wallen and Groves 1989, respectively). Mean gradients of NOCA survey reaches ranged from 0.8% on the Lower Stehekin River to 4.5% on Panther Creek, generally aligning with reaches from other studies reporting harlequin duck observations (basin data presented in Table 1).

Habitat associations

Habitat data were collected in many locations where harlequin ducks were observed during formal surveys, but not in unoccupied locations; therefore, we are unable to make predictions of harlequin occupancy and habitat suitability across NOCA streams. Habitat features recorded at harlequin duck observation sites were intended to be sampled widely across survey streams in order to determine factors that influence landscape scale, parkwide distribution, and to inform management of identified breeding habitat. In addition, there were not enough observations with habitat data outside the Stehekin River survey reach to infer stream-specific habitat variability; therefore, data from all streams were pooled for both adults and for broods.

Adult harlequin ducks were most frequently observed in streams with rapid and riffle habitat, cobble and boulder substrates, and single channel morphologies (e.g., straight, curved, meander). Similar results have been found in other Pacific breeding grounds (Bruner 1997, Wright et al. 2000, Morris et al. 2018), but it is apparent from our results, as well as other studies, that varied habitat is important. Across their range, harlequins are more frequently found in fast-running water and make use of both braided and single channel morphologies, often at relatively low gradients (Kuchel 1977, Wallen 1987). While lower-velocity habitat (e.g., pools, backwaters) was a significant, but less common feature of adult breeding habitat, it appeared to be relatively more important to broods. Kuchel (1977) reported a strong preference by broods for low velocity habitat during the first three weeks on the water, which transitioned to rapids thereafter.

Both adults and broods were most frequently observed in reaches with larger substrate sizes (cobble and boulder), echoed by results from other western US studies (Kuchel 1977, Wallen 1987, Cassirer and Groves 1994, and Bruner 1997). Bedrock substrate that is typical of rapid instream habitat was not observed, though positive correlations between bedrock substrate and harlequin duck presence have been demonstrated (Bruner 1997, Wright et al. 2000). Gravel and finer stream substrates were a small component of both adult and brood observation sites in NOCA streams, which may be related

to lower invertebrate abundance and difficulty in foraging. Aquatic invertebrates preferred by harlequin ducks, such as mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), and caddisflies (*Trichoptera sp.*), are common in running water with larger substrate sizes (Wright et al. 2000, Rodway 1998). The average channel width recorded at 12 brood observation sites (27.6 ± 15.7 m) was lower than that recorded at 114 adult observation sites (34.0 ± 16.8 m); although the sample size variability precludes meaningful comparison. Freeman and Goudie (2001) found that channel (wetted) width was one of the most important predictive variables to determine harlequin duck presence in the Upper Skagit River watershed, with channels over 10 m wide deemed as suitable. All but one of the width measurements taken at observation sites during NOCA surveys were at least 10 m wide.

Undercut banks, which are generally an indication of high flow events and unstable channel conditions, were lacking at most adult and brood sites. Such conditions can have many adverse effects on both adults and broods that include washing out nests as well as reducing food abundance and feeding efficacy due to increased sediment loads (Wright et al. 2000). Low bank relief may also be a preferred feature of brood-rearing streams because of the relative ease of detecting predators (MacCallum et al. 2016). Instream woody debris (e.g., ramps, bridges, drift) is another feature that is found in greater abundance in high energy systems with unstable banks. Our data suggest that harlequin ducks may prefer breeding streams with less woody debris. Machmer (2001) found that ramps, which can be favorable loafing objects, were important components of brood-rearing streams in southeastern British Columbia, but the majority of studies (Wallen and Groves 1989, Bruner 1997, Wright et al. 2000) suggest that less woody debris is preferred, especially in locations where broods were found. Exposed substrate (i.e., gravel bars) was preferred by both adults and broods, as reported from surveys of other breeding populations (Kuchel 1977, Wallen 1987, Machmer 2001, Morris et al. 2018). Such features provide highly utilized loafing sites (Bruner 1997) as well as low velocity refuges.

Mature trees with an overhanging canopy were the dominant riparian component at most adult and brood observation sites, while recently disturbed sites, characterized by young vegetation and exposed rocky substrate seemed to be less common. This association may largely be a function of availability, since most reaches are set within thick forest stands of mature conifers; however, overhanging mature riparian forest are known to be favorable to harlequin ducks by providing protective cover from predators, while lower shrub density allows for detection of predators (MacCallum et al. 2016). The importance of mature riparian forest types was also evident for other western breeding populations of harlequin ducks (Cassirer and Groves 1994, Machmer 2001), while shrubs were dominant across all breeding streams in the Priest River drainage (Wallen and Groves 1989). Findings from the Upper Skagit River (Freeman and Goudie 2001) and breeding streams around Prince William Sound, Alaska (Crowley 1994) detected no relationship with streamside vegetation. Differential habitat use across their range is probably an adaption to local environments and predator communities (MacCallum et al. 2016).

The same flexibility for habitat use likely applies when considering its relationship to human activities. Observations of both broods and adults where sites were adjacent (within 10 m) to human

activity were relatively rare, while sites over 50 m away from human activity were most common. Given detection biases, harlequin ducks may select for habitat close to human activities if more secluded locations lack preferred habitat features (Wallen 1987). This dynamic may be playing out in the lower Stehekin River, which appears to have the highest density of harlequin ducks and an abundance of preferable habitat features, but also the greatest human traffic of any known breeding streams in the Park Complex. Singleton and Long (2018) found that distribution and occupancy in Washington was unaffected by distance to nearest road, echoed by results in Oregon where harlequin ducks used areas with variable riparian corridor width (Bruner 1997).

Data Improvements

The difficulty of access to large stretches of breeding streams and the low densities of harlequin ducks can make detection problematic, emphasizing the need for standardized, effective survey efforts and methods. It is estimated that one effort-intensive survey can yield a detection probability of only 30–40% (Jarvis and Bruner 1997). Timing of surveys is a key factor influencing detection probability. On a sample of Washington streams, Singleton and Long (2018) estimated that the highest probability of detecting a harlequin duck during breeding season was 78% on April 19, then declined to 22% by May 26. Peak detection probability for productivity (post-breeding) surveys was 46% on July 7, then declined to 27% by August 25 (Singleton and Long 2018). Given that most occupancy and productivity surveys on NOCA streams were completed 3–4 weeks after April 19 (range: April 22 to June 17; Table 2) and 1–2 weeks after July 7 (range: June 30 to Sept 10) respectively, it is possible that occupancy and counts were underrepresented by many of our surveys. Future surveys should be focused within smaller periods in late April during the breeding season and in early July during the brood-rearing season to obtain the highest pair and brood counts possible.

Environmental DNA (eDNA) assays are a more sensitive monitoring tool that can identify trace quantities of DNA in water that arise from presence of aquatic species (Goldberg et al., 2015). Sampling for eDNA in water could thus significantly increase detectability of harlequin ducks on breeding streams. Working with collaborators at the National Genomics Center for Wildlife and Fish Conservation, we have successfully developed an eDNA assay for harlequin ducks and validated it *in vitro* against 20 other aquatic species (NPS/U.S. Forest Service, unpublished data). We are currently analyzing *in vivo* samples collected from streams in and around NOCA that were occupied by harlequin ducks, to determine how comprehensive eDNA surveys might be best designed. Employing this method for surveying harlequin ducks could help standardize monitoring methodology and alleviate some of the time and resources that traditional observational surveys require. This method is limited to confirming the presence of DNA in water samples and cannot be used to estimate abundance or density. Depending on future monitoring objectives, eDNA sampling may be used alone or as another data source to supplement harlequin duck visual surveys. If employed with visual surveys, it may serve to confirm occupancy determinations if no ducks are seen, and to further refine its efficacy as a primary monitoring tool.

Past surveys on NOCA streams include presence-only habitat data, but accurately estimating habitat selection and suitability will require data collection from a range of occupied and unoccupied sites. The relative importance of food availability and other breeding stream characteristics (e.g., vegetative cover, instream conditions) to site selection is not well understood despite the summaries provided in a number of studies (Bruner 1997, Wright et al. 2000, Wiggins 2005). The collection of additional covariates would help to evaluate habitat selection, resource availability, and factors playing into population trends. Flow data at observation sites and at known breeding reaches would be a useful parameter, as a supplement for USGS gauge data, to further define habitat preferences and future management objectives. Aquatic invertebrate sample data within NOCA harlequin duck survey reaches are lacking and should be added to the suite of other key habitat data in order to better estimate resource potential (McCutchen and Ydenberg 2013). Such data would also inform

management of NOCA waterways while complementing other habitat data collected from other land management units across the Cascades.

Migratory connectivity for harlequin ducks breeding in Washington is largely unknown. Surveys of major Salish Sea wintering grounds have been conducted (Nysewander et al. 2005), but we do not understand the predominant migration patterns that connect these coastal areas to inland breeding streams; therefore, it is difficult to evaluate the extent to which environmental conditions across life history phases contribute to population trends. Radio- or satellite-tagging individuals on breeding grounds early in the season may be the most effective technique to enhance our understanding of these relationships. The ability to track females on breeding streams would greatly assist with locating nests, which is valuable information for advising management and project decisions.

Current and Emerging Threats

As higher trophic consumers, harlequin ducks are especially vulnerable to environmental contaminants, human disturbances, and a changing climate. New threats to this species and aquatic ecosystems emerge on a routine basis, and many are conflated with the changing climate. During the next 20 to 40 years, the climate of the Pacific Northwest is projected to change significantly, and with potential consequences for hydrology at an ecosystem level. Predicted changes include warmer, drier summers, and warmer, wetter autumns and winters, resulting in diminished snowpack, earlier snowmelt, and an increase in extreme heat waves and precipitation events (Littel et al. 2009, Salathé et al. 2010, Mote and Salathé 2010). Warming water temperatures may negatively affect populations of aquatic invertebrates, which could lead to resource limitations for harlequin ducks (Harper and Peckarsky 2006, Herbst et al. 2019). Earlier snowmelt, longer growing season, earlier plant flowering and invertebrate emergence, and shifting migration phenology could all influence food availability and initiation of earlier breeding to synchronize with resource availability. These same biological shifts also portend earlier, and more frequent, visitor access to sensitive nesting areas in the Park Complex. Management of resources for Park managers is complicated, interconnected, dynamic, and often time-sensitive.

Some risks, such as environmental contamination through atmospheric deposition can be pervasive, even in protected areas. A study of 15 watersheds in western Canada suggested the primary contributor of mercury was atmospheric deposition (Guigueno et al. 2012). Other environmental contaminants may arise locally and be traced and mitigated at the source, such as heavy metals leaching from abandoned mines. In Quebec, Canada, mercury levels in feathers and chicks of osprey (*Pandion haliaetus*, a piscivorous raptor) were reported to be five times higher at reservoirs than at nearby ponds and lakes (DesGranges et al. 1998). Data on bioaccumulation of toxins and environmental contaminants in birds at NOCA are scarce. Two peregrine falcons (*Falco peregrinus*), one bald eagle (*Haliaeetus leucocephalus*), and one adult common loon (*Gavia immer*) have been recovered and tested for toxins and contaminants. Contaminants detected included lead, mercury, highly elevated iron, manganese, molybdenum, zinc, copper, cadmium, methyl mercury, and Aroclor 1260 (a polychlorinated biphenyl (PCB) that is most commonly used in large capacitors and transformers) (Christophersen and Ransom 2022). No harlequin duck carcasses have been recovered or tested within NOCA, to date.

An emerging and pervasive environmental contaminant, microplastic, is also a potential threat to piscivorous birds through bioaccumulation (Wagner et al. 2014). Microplastics are plastic fragments smaller than 5 mm that may pervade the environment through deposition. These microplastics are of great ecological concern in aquatic systems because they can be easily ingested and accumulate as indigestible matter throughout a food web. Study of this issue in aquatic organisms is ongoing in the Park Complex. Primary microplastics analyses (tissue digestions and ultraviolet detection) of gastrointestinal tracts from one of the falcons, the bald eagle, and a common loon recovered in NOCA did not detect any microplastics (Christophersen and Ransom 2022). While encouraging, this small sample size and basic analysis does not rule out the potentially serious risk that

bioaccumulation of microplastics in higher trophic level aquatic consumers, such as harlequin ducks, poses.

Harlequin ducks are generally known to be sensitive to certain types of human presence and disturbances, such as boating, rafting, fishing, and streamside camping, during the breeding season. Our data, as well as other studies (Bruner 1997, Singleton and Long 2018), suggest reaches that are farther from human activity are probably preferred, but not obligatory, for harlequin duck use. Moreover, female survival is lowest during breeding season compared to other life history phases (Bond et al. 2009); therefore, management actions intended to reduce mortality during this period are more likely to have significant population-level benefits. Limitation of some recreational activities in high-use breeding areas, especially those in the stream channel, during pre-nesting (late April through late May) and early brood-rearing (late June through late July) may improve protection of this species. Another important mitigation in areas where human and harlequin duck use overlaps may be to promote the growth of overhanging vegetation that reduces disturbance to harlequin ducks.

The impacts of Skagit River impoundment features (e.g., reservoirs, dams) on harlequin duck migration and broader ecology, are currently unknown. The Upper Skagit River (Canada) and tributaries of two Skagit River reservoirs, Ross and Diablo Lakes, are known harlequin duck breeding grounds. The loss of over 35 miles of running water habitat as a result of the three Skagit reservoirs may limit high-quality food sources and foraging opportunities for emigrating broods. Additional detriments for broods may include increased travel time, energy expenditure, exposure to predators, and dangers associated with 300–540 ft. vertical drops created by the three hydroelectric impoundments on the Skagit River. To date, there are no NOCA records of brood sightings on the mainstem Skagit River south of Hozomeen, but pairs of harlequin ducks have been observed on the reservoirs prior to breeding season.

Human-driven habitat alterations, along with associated human activity, can be highly disruptive in many ways. Instream modifications that disturb the streambed (e.g., culverts, bridges, bank stabilization) can mobilize sediment and reduce benthic macroinvertebrate density, which can limit harlequin duck resources and foraging efficacy. Similarly, human activity that contributes to the reduction of water quality (e.g., environmental contaminants, chronic sediment disruption) can reduce the productivity of preferred aquatic invertebrate prey that rely on near-pristine water quality levels. Channel or streambank alterations can also negatively affect habitat suitability if they prevent recruitment of large woody debris used for nesting, cover, and loafing sites, and if they reduce instream habitat complexity. Homogenization of instream habitat and increases of average water velocity within a given reach can be especially detrimental through a variety of mechanisms. These can include reducing the buffering capacity of high flow events and sedimentation, reducing flow refuges (i.e., eddies) for broods, and an increased probability of flooding nests (Cassirer and Groves 1994, Cassirer et al. 1996, Wright et al. 2000). Habitat modifications should be avoided within 50 m of channel edges, and when necessary, should be completed outside of the sensitive breeding periods. These recommendations are even more imperative on stream reaches with widths less than 20 m, on reaches with known nesting and brood rearing, and on reaches with historically high densities. Disturbance of such areas may negatively affect harlequin duck ecology.

Because harlequin ducks and multiple fish species generally have significant resource overlap, instream habitat management practices and protections that benefit fish also benefit harlequin ducks (Rockwell 2018). Conversely, multiple studies have shown that fish presence can reduce harlequin duck densities on otherwise suitable breeding reaches, probably by reducing availability of shared invertebrate prey species (McCutchen 2002, LeBourdais et al. 2009). The presence of introduced and non-native fish stocks such as eastern brook trout may artificially and disproportionately affect harlequin ducks. Removing or limiting the population growth of those species may benefit harlequin ducks. Other fisheries management objectives, such as native fish restoration, should consider potential impacts on known harlequin duck breeding reaches, such as indirect resource competition. If this dynamic is likely, nuanced considerations may be required to balance the needs of harlequin ducks with native fishes.

Several factors make harlequin ducks particularly susceptible to demographic impacts or extirpation of breeding populations following environmental disturbances. The effective population size of a watershed may naturally be very small due to low densities on breeding streams, slow reproductive rates, and their tendency to maintain long-term pair bonds, which may lead to reduced genetic diversity and hampered resilience to stochastic events (Schaffer 1981, Robertson et al. 2000). Strong site fidelity, and correspondingly low dispersal rates, can prolong or exacerbate population-level impacts (Iverson et al. 2004, Wiggins 2005). While the near-pristine breeding streams of NOCA and other National Parks in Washington likely serve as population refugia, many of the threats facing harlequin ducks act at large and distant scales. Mitigation of these impacts on NOCA's breeding populations would therefore benefit from unified efforts to research, monitor, and manage at the regional level. Standardized protocols and ecosystem management objectives would allow deeper data inference and more holistic conservation of harlequin ducks across the North Cascades Ecosystem.

Literature Cited

- Bengtson, S. A., and S. Ulfstrand. 1971. Food resources and breeding frequency of the harlequin duck *Histrionicus histrionicus* in Iceland. *Oikos* 22: 235–239.
- Bengtson, S. A. 1972. Breeding ecology of the harlequin duck *Histrionicus histrionicus* (L.) in Iceland. *Ornis Scandinavica*, Bent 1925: 1–19.
- Blackie, B. 2002. River-dependent bird species as potential indicators of ecosystem response to removal of dams on the Elwha River, Washington. M.S. Thesis. Oregon State University, Corvallis, Oregon.
- Bond, J. C., D. Esler, and T. D. Williams. 2008. Breeding propensity of female harlequin ducks. *Journal of Wildlife Management* 72: 1388–1393.
- Bond, J. C., S. A. Iverson, N. B. Maccallum, C. M. Smith, H. J. Bruner, and D. Esler. 2009. Variation in breeding season survival of female harlequin ducks. *Journal of Wildlife Management* 73: 965–972.
- Breault, A., and J. P. L. Savard. 1991. Status report on the distribution and ecology of harlequin ducks in British Columbia. Canadian Wildlife Service Technical Report no. 110. Pacific and Yukon Region, Delta, British Columbia, Canada.
- Bruner, H. J. 1997. Habitat use and productivity of harlequin ducks in the central Cascade Range of Oregon. M.S. Thesis. Oregon State University, Corvallis, Oregon.
- Cassirer, E. F., and C. R. Groves. 1989. Breeding ecology of harlequin ducks (*Histrionicus histrionicus*) on the Kaniksu National Forest, Idaho.
- Cassirer, E. F., and C. R. Groves. 1994. Ecology of harlequin ducks in Northern Idaho. Idaho Department of Fish and Game, Boise, Idaho.
- Cassirer, E. F., J. D. Reichel, R. L. Wallen, and E. C. Atkinson. 1996. Harlequin duck (*Histrionicus histrionicus*) United States Forest Service/Bureau of Land Management habitat conservation assessment and conservation strategy for the US Rocky Mountains. Unpublished technical report, Idaho Dept. of Fish and Game, Lewiston, Idaho.
- Christophersen, R. G., and J. I. Ransom. 2022. Osprey, peregrine falcon, and bald eagle nesting in North Cascades National Park Service Complex, Washington. Natural Resource Report NPS/NOCA/NRR—2022/2353. National Park Service, Fort Collins, Colorado.
<https://doi.org/10.36967/nrr-2289987>.
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2013. COSEWIC assessment and status report on the harlequin duck *Histrionicus histrionicus* Eastern population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 38 pp. Available at: www.registrelep-sararegistry.gc.ca/default_e.cfm.

- Crowley, D. W. 1994. Breeding habitat of harlequin ducks in Prince William Sound, Alaska. M.S. Thesis. Oregon State University, Corvallis, Oregon.
- Crowley, D. W. 1999. Productivity of harlequin ducks breeding in Prince William Sound, Alaska. Pages 14–20 in R. I. Goudie, M. R. Petersen, and G. J. Robertson, editors. Behaviour and ecology of sea ducks. Ottawa, Ontario, Canada.
- DesGranges, J., J. Rodrigue, B. Tardif, and M. Laperle. 1998. Mercury accumulation and biomagnification in ospreys (*Pandion haliaetus*) in the James Bay and Hudson Bay regions of Québec. Archives of Environmental Contamination and Toxicology 35: 330–341.
- Dzinbal, K. A. 1982. Ecology of harlequin ducks in Prince William Sound, Alaska, during summer. M.S. Thesis, Oregon State University, Corvallis, Oregon.
- eBird Basic Dataset. 2021. Version: EBD_relNov-2021. Cornell Lab of Ornithology, Ithaca, New York. Available at: <https://ebird.org/science/use-ebird-data>.
- Farrell, T. 1997. Harlequin duck breeding ecology on the Olympic Peninsula. M.S. Thesis. The Evergreen State College, Olympia, Washington.
- Fischer, J. B. 1998. Feeding behaviour, body condition, and oil contamination of wintering harlequin ducks (*Histrionicus histrionicus*) at Shemya Island, Alaska. M.S. thesis, University of Massachusetts, Amherst, Massachusetts.
- Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. General Technical Report PNW-8. USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 417 pp.
- Freeman, S., and R. I. Goudie. 1998. Abundance, distribution and habitat use of harlequin ducks in the Nahatlatch River. Report number CWRP 97-79 for Forest Renewal British Columbia, Ministry of Environment, Lands and Parks, Surrey, British Columbia, Canada.
- Freeman, S., and R. I. Goudie. 2001. Harlequin duck inventory of the Upper Skagit River watershed. Unpublished report for the Skagit Environmental Endowment Commission, North Vancouver, British Columbia, Canada.
- Goldberg, C. S., Strickler, K. M., and D. S. Pilliod. 2015. Moving environmental DNA methods from concept to practice for monitoring aquatic macroorganisms. Biological Conservation 18: 1–3.
- Guigueno, M. F., K. H. Elliot, and M. Wayland. 2012. Differential exposure of alpine ospreys to mercury: Melting glaciers, hydrology or deposition patterns? Environment International 40: 24–32.
- Hansen, W. K., L. J. Bates, and C. W. Breuner. 2014. Reproductive biology of breeding harlequin ducks in Glacier National Park. Intermountain Journal of Sciences 20: 97–98.

- Hansen, W., L. Bate, S. Gniadek, and C. W. Breuner. 2019. Influence of streamflow on reproductive success in a harlequin duck (*Histrionicus histrionicus*) population in the Rocky Mountains. *Waterbirds* 42: 411–424.
- Harper, M. P., and B. L. Peckarsky. 2006. Emergence cues of a mayfly in a high-altitude stream ecosystem: potential response to climate change. *Ecological Applications* 16: 612–621.
- Herbst, D. B., S. D. Cooper, R. B. Medhurst, S. W. Wiseman, and C. T. Hunsaker, C. T. 2019. Drought ecohydrology alters the structure and function of benthic invertebrate communities in mountain streams. *Freshwater Biology* 64: 886–902.
- Hunt, W. A. 1998. The ecology of harlequin ducks (*Histrionicus histrionicus*) breeding in Jasper National Park, Canada. M.S. thesis. Simon Fraser University, Burnaby, British Columbia, Canada.
- International Union for Conservation of Nature (IUCN). 2019. The IUCN Red List of Threatened Species. Version 2019-3. Available at: <https://www.iucnredlist.org/>.
- Iverson, S. A., D. Esler, and D. J. Rizzolo. 2004. Winter philopatry of harlequin ducks in Prince William Sound, Alaska. *The Condor* 106: 711–715.
- Jarvis, R. L., and H. J. Bruner. 1997. Probability of detection, and variance of spring surveys of harlequin ducks. Unpublished report, Oregon State University, Corvallis, Oregon.
- Kuchel, C. R. 1977. Some aspects of the behavior and ecology of harlequin ducks breeding in Glacier National Park, Montana. M.S. thesis. University of Montana, Missoula, Montana.
- LeBourdais, S. V., R. C. Ydenberg, and D. Esler. 2009. Fish and harlequin ducks compete on breeding streams. *Canadian Journal of Zoology* 87: 31–40.
- Littel, J. S., M. McGuire Elsner, L. W. Binder, and A. K. Snover. 2009. The Washington climate change impacts assessment: Evaluating Washington's future in a changing climate. Climate Impacts Group, University of Washington, Seattle, Washington.
- MacCallum, B., C. Feder, B. Godsall, M. I. Paibomesai, and A. Patterson. 2016. Habitat use by harlequin ducks (*Histrionicus histrionicus*) during brood-rearing in the Rocky Mountains of Alberta. *Canadian Wildlife Biology and Management* 5: 32–45.
- Machmer, M. M. 2001. Salmo River harlequin duck inventory, monitoring and brood assessment. Columbia Basin Fish and Wildlife Compensation Program and Pandion Ecological Research Ltd., Nelson, British Columbia, Canada.
- McCutchen, N. A. 2002. The response of stonefly (*Plecoptera*) nymphs to seasonal increases in predation risk. *Canadian Journal of Zoology* 80: 967–972.

- McCutchen, N. A., and R. C. Ydenberg. 2013. Harlequin duck *Histrionicus histrionicus* distribution and stonefly nymph availability in the Maligne Valley watershed a preliminary study. *Wildfowl* 55: 75–82.
- Morris, R. L., T. Chestnut, R. Gibbs, and J. I. Ransom. 2018. First harlequin duck (*Histrionicus histrionicus*) nest from Mount Rainier National Park, WA, in nearly 100 years. Unpublished technical report, Mount Rainier National Park, Ashford, Washington.
- Mote, P. W. 2003. Trends in snow water equivalent in the Pacific Northwest and their climatic causes. *Geophysical Research Letters* 30(12).
- Mote, P. W., and E. P. Salathé. 2010. Future climate in the Pacific Northwest. *Climatic Change* 102: 29–50.
- National Audubon Society. 2002. The Christmas Bird Count historical results [Online]. Available at: <https://www.audubon.org/conservation/science/christmas-bird-count>.
- NatureServe. 2019. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: <https://explorer.natureserve.org/>.
- Nysegwander, D. R., J. R. Evenson, B. L. Murphie, and T. A. Cyra. 2005. Report of marine bird and mammal component, Puget Sound Ambient Monitoring Program, for July 1992 to December 1999 period [Unpublished report]. Olympia, WA: Washington State Department of Fish and Wildlife, Wildlife Management Program. 181 pp.
- Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek, and D. R. Nysegwander. 1990. Immediate impact of the 'Exxon Valdez' oil spill on marine birds. *The Auk* 107: 387–397.
- Pojar, J., and A. MacKinnon. 1994. *Plants of the Pacific Northwest coast*. Lone Pine Publishing, Vancouver, British Columbia, Canada.
- Rawhouser, A. K., R. E. Holmes and R. S. Glesne. 2009. A survey of stream amphibian species composition and distribution in the North Cascades National Park Service Complex, Washington State (2005). Natural Resource Technical Report NPS/NCCN/NRTR—2009/169. National Park Service, Fort Collins, Colorado.
- Robertson, G. J. 1997. Pair formation, mating system, and winter philopatry in harlequin ducks. Ph.D. Dissertation. Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada.
- Robertson, G. J., F. Cooke, R. I. Goudie, and W. S. Boyd. 1998. The timing of pair formation in harlequin ducks. *The Condor* 100: 551–555.
- Robertson, G. J., and R. I. Goudie .1999. Harlequin duck (*Histrionicus histrionicus*), version 2.0. In: A. F. Poole and F. B. Gill (eds). *The birds of North America*. Cornell Lab of Ornithology, Ithaca, New York. Available at: <https://doi.org/10.2173/bna.466>.

- Robertson, G. J., F. Cooke, R. I. Goudie, and W. S. Boyd. 2000. Spacing patterns, mating systems, and winter philopatry in Harlequin Ducks. *The Auk* 117: 299–307.
- Rockwell, S. M. 2018. Conservation assessment for harlequin duck (*Histrionicus histrionicus*). Klamath Bird Observatory, Ashland, Oregon.
- Rodway, M. S. 1998. Activity patterns, diet, and feeding efficiency of Harlequin Ducks breeding in northern Labrador. *Canadian Journal of Zoology* 76: 902–909.
- Royan, A., D. M. Hannah, S. J. Reynolds, D. G. Noble and J. P. Sadler. 2014. River birds’ response to hydrological extremes: New vulnerability index and conservation implications. *Biological Conservation* 177: 64–73
- Salathé, E. P. Jr, L. R. Leung, Y. Qian, and Y. Zhang. 2010 Regional climate model projections for the State of Washington. *Climate Change*. Available at: <https://doi.org/10.1007/s10584-010-9849-y>.
- Schirato, G. 1994. Population and distribution of harlequin ducks in Washington State. Page 18 in: *Proceedings of the 2nd annual harlequin duck symposium*. 22 pp.
- Sea Duck Joint Venture. 2015. Sea duck information series: Harlequin duck (*Histrionicus histrionicus*). Species Fact Sheet, Sea Duck Joint Venture. Available at: https://seaduckjv.org/wp-content/uploads/2015/01/hard_sppfactsheet.pdf.
- Shaffer, M. L. 1981. Minimum population sizes for species conservation. *BioScience* 31: 131–134.
- Singleton, P. H., and L. Long. 2018. Harlequin duck occupancy and landscape-scale habitat associations on National Forest lands in Washington. U.S. Pacific Northwest Research Station, Wenatchee, Washington.
- Smith, C. M. 1996. Banff National Park harlequin duck research project: progress report – 1995 field season. Parks Canada, Banff, Alberta, Canada.
- Smith, C. M., F. Cooke, G. J. Robertson, R. I. Goudie, and W. S. Boyd. 2000. Long-term pair bonds in harlequin ducks. *The Condor* 102: 201.
- Taylor, W. P., and W. T. Shaw. 1927. *Mammals and birds of Mount Rainier National Park*. US Government Printing Office.
- U.S. Fish and Wildlife Service (USFWS). 1998. One-year finding for a petition to list the harlequin duck (*Histrionicus histrionicus*) in eastern North America as endangered or threatened. *Federal Register* 63(88): 25177–25178.
- Wagner, M., C. Scherer, D. Alvarez-Muñoz, N. Brennholt, X. Bourrain, S. Buchinger, E. Fries, C. Grosbois, J. Klasmeier, T. Marti, S. Rodriguez-Mozaz, R. Urbatzka, A.D. Vethaak, M. Winther-Nielsen, and G. Reifferscheid. 2014. Microplastics in freshwater ecosystems: what we know and what we need to know. *Environmental Sciences Europe* 26: 12.

- Wallen, R. L., and C. R. Groves. 1989. Distribution, breeding biology, and nesting habitat of harlequin ducks (*Histrionicus histrionicus*) in northern Idaho. Unpublished report, Idaho Department of Fish and Game, Boise, Idaho.
- Wallen, R. L. 1987. Habitat utilization by harlequin ducks in Grand Teton National Park. Doctoral dissertation, Montana State University-Bozeman, College of Letters and Science, Bozeman, Montana.
- Washington Department of Fish and Wildlife (WDFW). 2015. Washington's State Wildlife Action Plan: 2015 Update. Washington Department of Fish and Wildlife, Olympia, Washington.
- Washington Department of Fish and Wildlife (WDFW). 2019. Priority habitat and species list. Olympia, Washington. 292 pp.
- Washington Department of Fish and Wildlife (WDFW). 2021. Midwinter aerial seabird surveys. Available at: <https://wdfw.wa.gov/species-habitats/at-risk/species-recovery/seabirds/surveys-winter-aerial>.
- Wiggins, D. 2005. Harlequin duck (*Histrionicus histrionicus*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Available at: <http://www.fs.fed.us/r2/projects/scp/assessments/harlequinduck.pdf>.
- Wright, K. K., H. J. Bruner, J.L. Li, R. Jarvis, and S. Dowlan. 2000. The distribution, phenology, and prey of harlequin ducks, *Histrionicus histrionicus*, in a Cascade Mountain stream, Oregon. The Canadian Field-Naturalist 114: 187–195.

Appendix A. Harlequin duck survey details and habitat parameters

Tables A-1 through A-4 represent the harlequin duck survey locations, demographics, and habitat parameters for data collected in North Cascades National Park Service Complex, 1968–2021.

Table A-1. Summary of stream reaches surveyed by North Cascades National Park Service Complex staff (1990–2017).

Drainage	Survey Start (UTM)	Survey End (UTM)	Length (km)		
			Survey	Stream	% surveyed
Bacon Creek	615672E 5390481N	613716E 5392848N	5.4	23.5	22.8
Baker River	607249E 5402688N	613167E 5407526N	13.8	32.3	42.8
Big Beaver Creek	642243E 5404233N	629115E 5413299N	30.1	35.5	84.9
NF Cascade River	636279E 5370889N	640116E 5372589N	7.2	16.6	43.3
Chilliwack River	616208E 5428645N	612537E 5415864N	26.3	34.0	77.5
Goodell Creek	627764E 5392503N	622466E 5399161N	16.2	22.2	73.1
Lightning Creek	648498E 5417228N	647408E 5423460N	10.5	27.9	37.4
Little Beaver Creek	639157E 5419877N	622882E 5415226N	28.2	37.6	75.0
Newhalem Creek	628404E 5392375N	630910E 5385631N	11.9	20.7	57.5
Panther Creek	648982E 5396786N	647194E 5389897N	13.0	31.2	41.6
Stehekin River	672406E 5353992N	660357E 5360720N	16.6	48.6	34.2
Stetattle Creek	636112E 5397648N	632095E 5402324N	10.3	16.7	61.9
Thunder Creek	641174E 5393842N	644423E 5384981N	16.2	36.0	44.9
Total	–	–	205.7	382.8	53.6*

*Average % surveyed

Table A-2. Distribution of observations dates for harlequin duck demographic groups. Data represent all harlequin duck observations (surveyed and incidental) in North Cascades National Park Service Complex from 1968–2021.

Group	n	Interannual distribution of observation dates					
		First	1st Quartile	Median	Mean	3rd Quartile	Last
Male	81	Mar 24	Apr 26	May 17	May 19	May 26	Nov 5
Pair	135	Apr 5	Apr 26	May 2	May 6	May 17	Aug 15
Female	96	Apr 5	Jun 12	Jul 3	Jun 30	Jul 19	Oct 2
Brood	40	Jun 14	Jul 3	Jul 12	Jul 12	Jul 20	Aug 19

Table A-3. Distribution of observation site elevations for harlequin duck demographic groups. Data represent all harlequin duck observations (surveyed and incidental) in North Cascades National Park Service Complex (1968–2021).

Group	n	Interannual distribution of observation dates					
		First	1st Quartile	Median	Mean	3rd Quartile	Last
Male	27	98.0	350.0	362.0	373.6	451.0	837.0
Pair	40	104.0	329.8	361.0	344.3	375.0	600.0
Female	35	134.0	368.0	425.0	466.5	547.5	960.0
Brood	23	85.0	358.0	361.0	565.3	826.5	1192.0

Table A-4. Habitat parameters and their definitions used in evaluating sites of harlequin duck observations in North Cascades National Park Service Complex streams during surveys (1990–2017).

Habitat parameter	Variable	Definition
Stream habitat	Backwater	Off-channel habitat disconnected at the upstream end from the main channel
	Glide	Areas with low velocities and a smooth, unbroken surface
	Pocketwater	Run or riffle with boulders (> 30 cm in diameter), which create numerous small pools
	Pool	Deep, slow water areas
	Rapid	Fast moving water with high turbulence (white water)
	Riffle	Shallow areas with fast moving surface water that is broken by the stream substrate (white water)
	Run	Areas of deep, fast moving water with little or no turbulence
Stream substrate	Bedrock	Solid rock underlying loose deposits
	Boulder	>250 mm diameter
	Cobble	65–249 mm diameter
	Gravel	2–64 mm diameter
	Mud	Non-gritty, fine sediment
	Sand	0.06–2 mm gritty, fine sediment
Bank composition	Bedrock	Defined under stream substrate
	Debris	Remains of fallen dead trees or other organic material
	Gravel/cobble/boulder	Defined under stream substrate
	Grass/forbs	Herbaceous, non-woody vegetation
	Silt/sand	Defined under stream substrate
	Shrubs	Predominantly deciduous plants, 3–15 ft tall
	Trees	Coniferous and deciduous plants >16 ft tall
Overstory composition	Mature	100–160 years old, DBH 14–20 in
	Old-growth	Over 160 years old or DBH > 20 in

Table A-4 (continued). Habitat parameters and their definitions used in evaluating sites of harlequin duck observations in North Cascades National Park Service Complex streams during surveys (1990–2017).

Habitat parameter	Variable	Definition
Overstory composition (continued)	Shrub	Predominantly deciduous plants, 3–15 ft tall
	Young	70–100 years old, DBH 14–20 in
Channel type	Braided	Multiple small, shallow channels and islands that shift during peak flow periods
	Curved	Single channel structurally controlled by a confined valley, more acutely angled curves than a meander
	Meander	Shifting single channel with sinuous curves located in a flat-bottomed valley with deep pools separated by shallow riffles
	Straight	Single, unidirectional channel structurally controlled by a confined valley, generally with fast moving water (rapids, runs)
Human access	Accessible	> 50 m from human activity, connected by maintained trail
	Adjacent	< 10 m from human activity
	Inaccessible	> 50 m from human activity, not connected by maintained trail
	Near	> 10 m and < 50 m from human activity
Woody debris	Bridge	Log across stream
	Collapsed bridge	Log that extends across stream, but is submerged in middle
	Ramp	One end of log in stream and other on bank
	Drift	Log floating in stream
Islands	Present/absent	Mid-channel dry land
Gravel bars	Present/absent	Exposed (unvegetated) gravel/cobble/boulder either on stream bank or islands
Vegetative overhang	Present/absent	Vegetation overhanging the wetted channel
Undercut bank	Present/absent	Overhanging stream bank eroded by water
Stream width	Continuous value (m)	Wetted width of stream perpendicular to direction of flow

Appendix B. Harlequin duck and associated species observations

Table B-1 presents harlequin duck and associated species observations collected during surveys conducted from 1990–2017, and Table B-2 presents incidental harlequin duck observations from 1968–2021 in North Cascades National Park Service Complex.

Table B-1. Observations of harlequin ducks and associated species made during occupancy and productivity surveys in North Cascades National Park Service Complex streams (1990–2017). Dashes = no observations.

Survey information			HADU	Associated Species ^b				Grand Total
Year	Drainage	Date		AMDI	BEKI	COME	SPSA	
1990	Stehekin River	May 17	23	–	2	9	5	39
	Stehekin River	Jun 12 ^a	18	2	–	4	29	53
	Stehekin River	Jul 2 ^a	18	2	2	13	9	44
	Stehekin River	Jul 3	25	–	4	7	26	62
	Stehekin River	Aug 7 ^a	15	–	–	16	22	53
	Stehekin River	Sep 6 ^a	–	1	5	15	17	38
1991	Stehekin River	Apr 26	29	–	–	–	–	29
	Stehekin River	May 14 ^a	24	–	–	–	–	24
	Stehekin River	May 28 ^a	14	–	–	–	–	14
	Stehekin River	Jun 13 ^a	21	–	–	–	–	21
	Stehekin River	Jul 2	8	–	–	–	–	8
	Stehekin River	Jul 24 ^a	3	–	–	–	–	3
	Stehekin River	Aug 13 ^a	5	2	–	–	–	7
	Stehekin River	Sep 10 ^a	–	10	–	–	–	10
1993	Stehekin River	Apr 23 ^a	29	–	–	–	–	29
	Stehekin River	Apr 26	37	–	–	2	–	39
	Stehekin River	May 20 ^a	11	–	–	–	–	11
	Stehekin River	May 24 ^a	22	–	–	–	–	22
	Stehekin River	Jun 17 ^a	15	–	–	–	–	15
	Stehekin River	Jul 1	13	–	–	–	–	13
	Stehekin River	Aug 13 ^a	11	–	–	–	–	11
1994	Stehekin River	Apr 27	29	–	–	–	–	29
	Stehekin River	May 25 ^a	12	–	–	–	–	12
	Stehekin River	Jun 13 ^a	13	–	–	–	–	13

^aCounts are excluded from analyses.

^bSpecies codes: HADU = harlequin duck; AMDI = American dipper; BEKI: belted kingfisher; COME = common merganser; SPSA = spotted sandpiper.

Table B-1 (continued). Observations of harlequin ducks and associated species made during occupancy and productivity surveys in North Cascades National Park Service Complex streams (1990–2017).

Dashes = no observations.

Survey information			HADU	Associated Species ^b				Grand Total
Year	Drainage	Date		AMDI	BEKI	COME	SPSA	
1994 (cont.)	Stehekin River	Jul 19	4	–	–	–	–	4
	Stehekin River	Sep 1 ^a	3	–	–	–	–	3
1995	Stehekin River	Apr 22	13	–	–	–	–	13
	Stehekin River	Jul 25	4	–	–	–	–	4
1996	Stehekin River	May 18	14	–	–	–	–	14
	Stehekin River	Jul 11	6	–	–	–	–	6
1997	Newhalem Creek	May 27–28	5	–	–	–	–	5
	Newhalem Creek	Jul 16–17	5	–	–	–	–	5
	Stehekin River	May 17	20	–	–	–	–	20
	Stehekin River	Jun 10 ^a	3	–	–	–	–	3
	Stehekin River	Jul 8	2	–	–	–	–	2
1998	Goodell Creek	May 11–12	1	8	–	1	–	10
	Goodell Creek	Jul 6–8	–	11	–	3	3	17
	Panther Creek	May 19–21	–	6	–	–	–	6
	Panther Creek	Jul 9	–	6	–	–	–	6
	Stehekin River	May 2	25	–	1	6	2	34
	Stehekin River	Jul 17	20	3	–	12	13	48
	Stetattle Creek	May 12–13	–	7	–	–	–	7
	Stetattle Creek	Jun 30–Jul 1	–	3	–	2	–	5
1999	Bacon Creek	May 11	–	4	–	–	–	4
	Baker River	May 12–13	4	5	1	4	2	16
	Stehekin River	May 21	17	–	3	6	43	69
	Stehekin River	Jul 17	9	2	1	6	4	22
2000	Chilliwack River	May 22	1	1	–	1	1	4
	Chilliwack River	Jul 21–22	4	–	–	–	3	7
	NF Cascade River	May 10–11	–	5	–	1	–	6
	NF Cascade River	Jul 20	–	3	–	–	–	3
	Stehekin River	May 17	19	–	2	8	11	40
2001	Big Beaver Creek	May 8–9	3	11	–	3	–	17
	Big Beaver Creek	Jul 17–18	1	5	–	–	2	8
	Little Beaver Creek	May 22–24	2	1	–	–	–	3
	Little Beaver Creek	Jul 16–18	8	–	–	–	–	8

^aCounts are excluded from analyses.

^bSpecies codes: HADU = harlequin duck; AMDI = American dipper; BEKI: belted kingfisher; COME = common merganser; SPSA = spotted sandpiper.

Table B-1 (continued). Observations of harlequin ducks and associated species made during occupancy and productivity surveys in North Cascades National Park Service Complex streams (1990–2017). Dashes = no observations.

Survey information			HADU	Associated Species ^b				Grand Total
Year	Drainage	Date		AMDI	BEKI	COME	SPSA	
2002	Lightning Creek	May 16–17	–	6	–	3	–	9
	Lightning Creek	Jul 17–18	–	--	–	–	–	--
	Thunder Creek	May 21–22	4	5	–	–	1	10
	Thunder Creek	Jul 23–25	1	3	1	--	1	6
2015	Newhalem Creek	May 28	–	18	–	–	–	18
	Stehekin River	Jul 28	4	–	–	–	–	4
	Stehekin River	Aug 5 ^a (inc)	6	–	–	–	–	6
2016	Chilliwack River	Jun 1	–	1	–	–	1	2
	Little Beaver Creek	May 23–24	1	2	–	1	1	5
	Newhalem Creek	May 10	–	3	–	–	–	3
	Stehekin River	May 3–5	8	–	–	–	–	8
	Stehekin River	Jul 13	7	–	–	11	1	19
	Thunder Creek	May 17	2	3	–	1	–	6
2017	Stehekin River	May 11	2	–	–	–	–	2
Grand Total	–	68	623	139	22	135	197	1116

^aCounts are excluded from analyses.

^bSpecies codes: HADU = harlequin duck; AMDI = American dipper; BEKI: belted kingfisher; COME = common merganser; SPSA = spotted sandpiper.

Table B-2. Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$). Observations without dates are not included. Unk = unknown age and sex. Dashes = no observations.

Drainage	Date	Total adults	Pairs	Unpaired Males	Unpaired Females	Juveniles	Unk
Bacon Creek ($n = 5$)	5/1/1997	2	1	–	–	–	–
	6/5/1998	1	–	–	1	–	–
	6/15/1998	1	–	–	1	–	–
	6/16/1998	–	–	–	–	–	1
	6/17/2002	1	–	–	1	–	–
Baker River ($n = 2$)	5/16/1993	1	–	1	–	–	–
	10/2/2003	1	–	–	1	–	–
Big Beaver Creek ($n = 9$)	6/15/1987	1	–	–	1	–	–
	8/2/1992	1	–	–	1	–	–
	8/17/1994	–	–	–	–	–	1

Table B-2 (continued). Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$). Observations without dates are not included. Unk = unknown age and sex. Dashes = no observations.

Drainage	Date	Total adults	Pairs	Unpaired Males	Unpaired Females	Juveniles	Unk
Big Beaver Creek ($n = 9$)	7/15/1996	2	–	–	2	–	–
	7/29/1996	2	–	–	2	–	–
	5/29/1999	1	–	1	–	–	–
	6/13/1999	3	–	–	3	–	–
	6/14/1999	3	–	3	–	–	–
	5/27/2004	1	–	1	–	–	–
Cascade River ($n = 1$)	5/8/2017	2	1	–	–	–	–
NF Cascade River ($n = 1$)	5/1/2017	2	1	–	–	–	–
Chilliwack River ($n = 2$)	7/4/1983	1	–	–	1	4	–
	7/26/2000	1	–	–	1	2	–
Goodell Creek ($n = 10$)	4/20/1984	2	1	–	–	–	–
	6/12/1986	2	1	–	–	–	–
	8/15/1994	4	1	–	2	–	4
	8/25/1994	4	–	–	4	–	–
	5/12/1995	2	1	–	–	–	–
	7/11/1995	1	–	–	1	1	–
	6/5/1996	1	–	–	1	–	–
	5/4/2001	2	1	–	–	–	–
	9/23/2004	–	–	–	–	–	1
	8/9/2011	–	–	–	–	–	1
Hozomeen Creek ($n = 1$)	6/29/1999	1	–	–	1	–	–
Little Beaver Creek ($n = 1$)	7/15/1984	1	–	–	1	–	–
Newhalem Creek ($n = 6$)	5/12/1992	4	1	2	–	–	–
	5/24/1992	1	–	–	1	–	–
	5/8/1997	1	–	1	–	–	–
	4/29/1999	2	1	–	–	–	–
	5/10/2001	1	–	1	–	–	–
	10/28/2003	1	–	1	–	–	–
Ruby Creek ($n = 2$)	6/27/1994	1	–	–	1	–	–
	4/24/2017	1	–	1	–	–	–

Table B-2 (continued). Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$). Observations without dates are not included. Unk = unknown age and sex. Dashes = no observations.

Drainage	Date	Total adults	Pairs	Unpaired Males	Unpaired Females	Juveniles	Unk
Skagit River ($n = 24$)	6/2/1972	5	2	1	–	–	–
	6/17/1979	–	–	–	–	–	2
	5/11/1984	3	1	1	–	–	–
	6/2/1986	1	–	1	–	–	–
	6/30/1987	1	–	1	–	–	–
	6/22/1988	1	–	–	1	–	–
	6/27/1992	1	–	–	1	4	–
	4/10/1994	2	1	–	–	–	–
	4/28/1996	2	1	–	–	–	–
	5/1/1999	2	–	2	–	–	–
	5/12/2000	4	1	–	2	–	–
	8/20/2000	–	–	–	–	–	12
	6/23/2002	1	–	1	–	–	–
	4/16/2003	–	–	–	–	–	1
	5/15/2011	–	–	–	–	–	1
	4/20/2012	–	–	–	–	–	1
	4/29/2012	–	–	–	–	–	3
	5/2/2012	–	–	–	–	–	2
	6/1/2012	–	–	–	–	–	1
	6/27/2012	–	–	–	–	–	1
	4/20/2013	–	–	–	–	–	1
	8/8/2013	–	–	–	–	–	1
	4/21/2017	2	1	–	–	–	–
	5/5/2017	2	1	–	–	–	–
Stehekin River ($n = 87$)	8/4/1968	–	–	–	–	–	1
	4/26/1969	–	–	–	–	–	2
	6/1/1969	–	–	–	–	–	–
	5/12/1973	–	–	–	–	–	30
	4/25/1974	2	1	–	–	–	–
	11/5/1975	1	–	1	–	–	–
	3/20/1981	–	–	–	–	–	3
	8/15/1983	–	–	–	–	–	3
	3/24/1984	2	–	2	–	–	–
	4/12/1984	–	–	–	–	–	4

Table B-2 (continued). Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$). Observations without dates are not included. Unk = unknown age and sex. Dashes = no observations.

Drainage	Date	Total adults	Pairs	Unpaired Males	Unpaired Females	Juveniles	Unk
Stehekin River ($n = 87$) (continued)	8/17/1984	2	–	–	2	–	–
	7/21/1985	1	–	–	1	2	–
	7/30/1985	–	–	–	–	2	–
	7/31/1985	–	–	–	–	–	1
	8/27/1985	–	–	–	–	–	2
	4/22/1986	3	1	1	–	–	–
	9/3/1986	–	–	–	–	–	2
	5/5/1987	4	2	–	–	–	–
	6/24/1987	1	–	–	1	3	–
	5/25/1988	1	–	1	–	–	–
	5/26/1988	–	–	–	–	–	1
	6/15/1988	1	–	–	1	2	–
	7/5/1988	1	–	–	1	6	–
	7/31/1988	3	–	–	3	–	–
	6/24/1989	1	–	–	1	4	–
	7/10/1989	1	–	–	1	–	–
	7/12/1989	1	–	–	1	4	–
	8/19/1989	–	–	–	–	5	–
	4/5/1990	3	1	–	1	–	–
	4/16/1990	2	1	–	–	–	–
	6/4/1990	2	1	–	–	–	–
	7/5/1990	–	–	–	–	–	1
	10/11/1990	–	–	–	–	–	1
	7/17/1992	1	–	–	1	5	–
	8/23/1992	–	–	–	–	–	2
	9/14/1992	–	–	–	–	–	4
	9/20/1992	–	–	–	–	–	1
	4/10/1993	1	–	1	–	–	–
	4/11/1993	4	2	–	–	–	–
	4/13/1993	–	–	–	–	–	2
	4/19/1993	1	–	1	–	–	–
	5/3/1993	2	1	–	–	–	–
	5/25/1993	2	1	–	–	–	–
	7/8/1993	–	–	–	–	–	–

Table B-2 (continued). Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$). Observations without dates are not included. Unk = unknown age and sex. Dashes = no observations.

Drainage	Date	Total adults	Pairs	Unpaired Males	Unpaired Females	Juveniles	Unk
Stehekin River ($n = 87$) (continued)	7/22/1993	3	–	–	3	–	–
	7/29/1993	1	–	–	1	–	–
	6/21/1994	1	–	–	1	6	–
	6/22/1994	2	–	2	–	–	1
	7/8/1994	1	–	–	1	–	–
	4/20/1995	2	1	–	–	–	–
	7/20/1995	1	–	–	1	–	–
	9/21/1995	1	–	–	1	–	–
	5/28/1996	2	1	–	–	–	–
	5/29/1996	2	–	2	–	–	–
	6/2/1996	2	–	2	–	–	–
	6/13/1996	1	–	–	1	–	–
	7/7/1996	1	–	–	1	5	–
	4/11/1997	2	1	–	–	–	–
	4/12/1997	2	1	–	–	–	–
	4/21/1997	–	–	–	–	–	–
	5/17/1997	2	1	–	–	–	–
	4/22/1998	1	–	1	–	–	–
	6/27/1998	1	–	–	1	–	–
	4/10/1999	–	–	–	–	–	1
	7/23/1999	–	–	–	–	–	2
	7/28/1999	1	–	–	1	–	–
	5/11/2000	2	1	–	–	–	–
	6/11/2000	6	1	–	4	–	–
	7/2/2000	1	–	–	1	6	–
	8/1/2000	2	–	–	2	–	–
	5/12/2011	–	–	–	–	–	1
	6/4/2011	–	–	–	–	–	1
	8/5/2015	1	–	–	1	5	–
	5/3/2016	3	–	–	–	–	–
	5/20/2016	1	–	–	–	–	–
	7/10/2016	1	–	–	–	–	–
	8/2/2016	1	–	–	–	–	–
	8/3/2016	1	–	–	1	–	–

Table B-2 (continued). Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$). Observations without dates are not included. Unk = unknown age and sex. Dashes = no observations.

Drainage	Date	Total adults	Pairs	Unpaired Males	Unpaired Females	Juveniles	Unk
Stehekin River ($n = 87$) (continued)	5/21/2017	2	1	–	–	–	–
	5/22/2017	2	1	–	–	–	–
	6/14/2017	1	–	–	1	4	–
	6/15/2018	2	–	–	2	–	–
	7/22/2019	1	–	–	1	4	–
	4/12/2021	1	–	1	–	–	–
	6/15/2021	1	–	1	–	–	–
Thunder Creek ($n = 35$)	4/12/1970	–	–	–	–	–	1
	5/22/1971	–	–	–	–	–	3
	6/24/1979	1	–	1	–	–	–
	5/6/1982	2	1	–	–	–	–
	4/23/1984	10	5	–	–	–	–
	4/20/1988	4	1	2	–	–	–
	5/19/1991	2	1	–	–	–	–
	6/9/1991	2	1	–	–	–	–
	6/21/1991	1	–	–	1	–	–
	5/22/1992	–	–	–	–	–	2
	6/17/1992	1	–	–	1	–	–
	7/28/1992	1	–	–	1	–	–
	8/28/1992	–	–	–	–	–	2
	5/26/1993	1	–	1	–	–	–
	6/3/1993	2	1	–	–	–	–
	4/19/1994	2	1	–	–	–	–
	4/27/1994	–	–	–	–	–	1
	5/11/1994	–	–	–	–	–	1
	5/24/1994	2	1	–	–	–	–
	6/24/1995	1	–	–	1	–	–
	8/9/1995	1	–	1	–	–	1
	8/14/1995	2	–	–	2	–	–
	5/27/1996	–	–	–	–	–	1
	6/6/1998	2	1	–	–	–	–
	6/16/1998	2	1	–	–	–	–
	8/13/1998	1	–	1	–	–	–
	8/17/1998	2	–	–	2	–	–

Table B-2 (continued). Incidental observations of harlequin ducks in North Cascades National Park Service Complex streams, 1968–2021 ($n = 184$). Observations without dates are not included. Unk = unknown age and sex. Dashes = no observations.

Drainage	Date	Total adults	Pairs	Unpaired Males	Unpaired Females	Juveniles	Unk
Thunder Creek ($n = 35$) (continued)	4/13/1999	5	1	3	–	–	–
	5/20/1999	2	1	–	–	–	–
	8/5/2000	1	–	–	1	4	–
	7/23/2001	1	–	–	1	2	–
	8/1/2001	3	–	–	3	2	–
	5/17/2003	4	2	–	–	–	–
	6/10/2004	1	–	1	–	–	–
	4/26/2017	2	1	–	–	–	–
Totals	–	248	57	45	83	82	112

Appendix C. Data sheet for harlequin duck surveys

HARLEQUIN DUCK SURVEY DATA FORM					
Observation # _____		Date ____ / ____ / ____		Time _____ Pdt	
Observers: _____					
Location: UTM N _____,		UTM E _____			
Description: _____					
Composition: # Males _____ # Females _____ #Young _____					
Activities: _____					
HABITAT ATTRIBUTES					
(circle one)		(circle one)		(circle one)	
STREAM		STREAM		BANK	
HABITAT		SUBSTRATE		COMPOSITION	
PO Pool		MU Mud		TR Trees	L R
RI Riffle		SA Sand		SH Shrubs	L R
RU Run		GR Gravel		GF Grass/Forbs	L R
PW Pocketwater		CO Cobble		BD Bedrock	L R
GL Glide		BO Boulder		SS Silt/Sand	L R
RA Rapid		BE Bedrock		GC Grav/Cob/Bold	L R
BA Backwater				DE Debris	L R
(circle one)		(circle one)		(circle one)	
CHANNEL TYPE		HUMAN ACCESS		OVERSTORY	
ME Meander		AD Adjacent		SR Shrub	L R
BR Braided		NE Near		YG Young	L R
ST Straight		AC Accessible		MA Mature	L R
CU Curved		IN Inaccessible		OG Old-growth	L R
DEBRIS: (# of each type within 10 m)					
BG Bridge	_____			LS Loafing Sites	_____
CB Collapsed Bridge	_____			SW Stream Width	_____
RA Ramp	_____				
DR Drift	_____				
IS Islands	Y N	Vegetative Overhang		Y N	
GB Gravel Bars	Y N	Bank Undercut		Y N	
Comments: _____					

Figure C-1. Image of data sheet used by North Cascades National Park Service Complex staff for observations of harlequin ducks during formal surveys, 1990–2017. The data sheet's text is provided below.

North Cascades National Park Service Complex Harlequin Duck Data Sheet Text

Harlequin Duck Survey Data Form

Observation #: (text field)

Date: (text field, separated by day, month, and year)

Time (PDT): (text field)

Observers: (text field)

Location:

UTM N (text field)

UTM E (text field)

Description: (text field)

Composition:

Males (text field)

Females (text field)

Young (text field)

Activities: (text field)

Habitat Attributes:

Stream Habitat (circle one):

PO Pool

RI Riffle

RU Run

PW Pocketwater

GL Glide

RA Rapid

BA Backwater

Stream Substrate (circle one):

MU Mud

SA Sand

GR Gravel

CO Cobble

BO Boulder

BE Bedrock

Bank Composition (circle one):

TR Trees (circle L or R for Left or Right)

SH Shrubs (circle L or R for Left or Right)

GF Grass/Forbs (circle L or R for Left or Right)

BD Bedrock (circle L or R for Left or Right)

SS Silt/Sand (circle L or R for Left or Right)

GC Grav/Cob/Bold (circle L or R for Left or Right)
DE Debris (circle L or R for Left or Right)

Channel Type (circle one):

ME Meander
BR Braided
ST Straight
CU Curved

Human Access (circle one):

AD Adjacent
NE Near
AC Accessible
IN Inaccessible

Overstory (circle one):

SH Shrub (circle L or R for Left or Right)
YG Young (circle L or R for Left or Right)
MA Mature (circle L or R for Left or Right)
OG Old-growth (circle L or R for Left or Right)

Debris (# of each type within 10 m)

BG Bridge (text field)
CB Collapsed Bridge (text field)
RA Ramp (text field)
DR Drift (text field)
LS Loafing Sites (text field)
SW Stream Width (text field)

IS Islands (circle one)

Y
N

GR Gravel Bars (circle one)

Y
N

Vegetation Overhang (circle one)

Y
N

Bank Undercut (circle one)

Y
N

Comments (text field):



A female harlequin duck with her newly-hatched brood. NPS / ROY MORRIS

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 168/180054, April 2022

National Park Service
U.S. Department of the Interior



[Natural Resource Stewardship and Science](#)

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525