AN INVESTIGATION OF FOOD AVAILABILITY AND NESTING HABITS OF THE HARLEQUIN DUCK (HISTRIONICUS HISTRIONICUS) ON THE OLYMPIC PENINSULA

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An Investigation Of Food Availability And Nesting Habits Of The Harlequin Duck (*Histrionicus histrionicus*) On The Olympic Peninsula

by

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ABSTRACT

The objective of the paper is to better understand the habits of the Harlequin duck (*Histionicus histrionicus*) to aid in Washington State's efforts to protect this species. The paper begins with an introduction to the life history of the Harlequin duck through a literature review and a habitat characterization. Following this is data and analysis regarding nest initiation timing relative to stream flow and a preliminary comparison of Harlequin duck distribution on the streams of the Olympic Peninsula to benthic invertebrate density.

The Harlequin duck is impacted by flood activity brought about by spring snow melt on the interior mountain streams of its Western U.S. distribution. Data gathered by brood surveys for the Washington State department of Fish and Wildlife was used to determine the influence of spring stream flow regimes on the nest initiation of Harlequins. From the data analyzed in this paper there was found to be no significant difference in the mean nest initiation times of Harlequin ducks on the streams of the Olympic Peninsula. Further there was no correlation between daily average stream flow and the range of nest initiation times for the years 1991-94 and 1996.

It is also well documented that the Harlequin duck utilizes the abundance of benthic freshwater larvae as a food source while on the breeding grounds. Using data collected by the Washington Department of Ecology benthic invertebrate densities were correlated to the occurrence of Harlequin ducks in pool and riffle habitats. On the breeding grounds of the Olympic Peninsula there is a significant difference between benthic invertebrate densities in the riffle habitat of streams that support Harlequin ducks

and the riffle habitat of streams that do not support Harlequin ducks. There is no significant difference for the pool habitats compared for benthic invertebrate densities with and without Harlequin ducks.

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CHAPTER ONE: INTRODUCTION

There are three objectives to this study: First, it is an exploration of the ecology of the Harlequin duck (*Histrionicus histrionicus*) bearing in mind the topography, water regime and riparian ecosystem of the Olympic Peninsula. Second, it is an original coordination of brood survey data, stream flow data and invertebrate density data with the objective of learning more about this species in its breeding habitat on the Olympic Peninsula. Third, it is an in-depth and critical look at the management practices and current issues surrounding the Harlequin in Western Washington.

Understanding food resources, habitat characteristics, stream morphology and the biology of the bird all have important bearing on the successful protection of the Harlequin duck and biodiversity. The integration of physiology and behavior evolved by the Harlequin to survive is fascinating in its scope and refinement. The management policy for the Harlequin is incomplete because the understanding of its needs and pertinent threats are lacking.

The impetus of this paper is to make a critical assessment of the nature of information and management practices regarding the Harlequin duck on the Olympic Peninsula and to come up with some original conclusions about this species. The unique position of the Harlequin as an indicator species and a link between the coast and the mountain streams creates an opportunity to use this duck as a guide in the management of wildlife that shares the breeding and wintering habitats with them.

Effective Harlequin management relies on harvest provisions, habitat protection and conservation. The gaps in our knowledge of this species creates weaknesses and limitations in our ability to fully understand, and better manage these birds. These deficiencies include poor harvest limits set by the evaluation of dabbling duck populations, reliable information on diving duck harvest (Wick & Jeffrey 1966), the incomplete evaluation of regional biology and habitat requirements, and the analysis, synthesis and implementation of known data.

The Harlequin duck is not steeped in controversy and social issues to the same extent as the Spotted owl (*Strix occidentalis*) or the Marbled murrelet (*Brachyramphus marmoratus*). Nonetheless, as a species officially regarded by the Washington State Department of Fish and Wildlife as a Priority Species, by the U.S. Forest Service in the adjacent regions as a Species of Special Concern and at one time a Category 2 candidate under the Endangered Species Act, the Harlequin duck warrants special attention and as complete an understanding as is possible.

The Washington State Growth Management Act (1990) regards the list of State Priority Habitats and Species when planning and development are regulated. This is particularly important because one premise of this paper is that the consideration of Harlequin duck breeding and wintering habitat during relevant times of the year for lowered impact, conservation and further study is necessary in order to provide better management for this species.

The Harlequin duck is a species about which too little is known. It is a fascinating bird that alternates wintering and breeding environments throughout its range and utilizes the harshest zones of these habitats, namely turbulent and fast moving water. This species spends the winters in the coastal environments of the northern Pacific and Atlantic Oceans. In the spring, pairs migrate upstream to breed in the active channel of the rivers where the females were hatched and raised.

Harlequin ducks have evolved several behavioral characteristics to overcome the rigors of inhabiting the fast waters of the active channel of a river that is their breeding habitat. Research indicates that in their Rocky Mountain breeding range nests initiated before the peak runoff from snow melt can be devastated by the increased flow.

Harlequin ducks are regarded as late nesters and this behavior has been linked to the increased stream flow events that regularly occur on the interior glacially fed streams of their Rocky Mountain breeding habitats. High spring stream flow is devastating to nests and broods because they can be washed away. The males leave shortly after incubation begins for the coastal habitat and the females are unable to replace this loss. A comparison of nest initiation and stream flow data would be a good indication as to whether or not the spring precipitation events impact the survival of this species along the breeding habitat of the

Olympic Peninsula.

The impact of food availability and abundance on the breeding habitat of the Harlequin duck is unknown for the state of Washington. Currently there is no quantitative data concerning exactly what these birds consume while living on the rivers. It has been well documented that they are opportunistic feeders of invertebrate species in both of their habitats. Some of the best data for this are their selection of prey items on the rivers of their Icelandic distribution where the most abundant insect larvae, Dipterans, constitute the majority of their diet (Bengtson 1966; 1972; Gaines 1993; Gardarsson and Einarsson 1994). The preliminary comparison of invertebrate densities on streams with and without Harlequin ducks on the Olympic Peninsula can provide a base of knowledge that will be useful in further studies.

The issues of concern for this paper are some aspects of their reproductive biology, specifically the timing of nest initiation relative to the fluctuation of stream flow, duration of nesting correlated to daily average streamflow and the distributive influence of relative invertebrate densities on streams with and without Harlequin ducks. This paper will introduce the reader to the Harlequin, investigate briefly the habitat characteristics related to this species on the Olympic Peninsula, and provide a comparison and analysis of brood survey, stream flow and invertebrate density data from which further study and management recommendations will be made based on the history and policy of the study area.

Chapter two based on a thorough literature review, is a summary of the ecology of the Harlequin duck. The third chapter discusses the habitat characteristics and present understanding of this bird along the riparian corridors through short accounts of riparian ecology, habitat requirements and Harlequin duck production.

Chapters four and five are a culmination of learning and understanding. They introduce, analyze and discuss an original correlation of governmental data records for stream flow (United States Geological Survey) and invertebrate densities (Washington State Department of Ecology) with the activities of Harlequin ducks on the breeding habitat of the Olympic Peninsula. Chapter six is an introduction to the study area through geologic events and recent human impacts covering the Olympic National Park and Forest, some historical events, current threats and habitat management. Chapter six concludes with recommendations based on chapters two through five and a desire to perpetuate this species far into the future.

CHAPTER TWO: THE HARLEQUIN DUCK

Introduction

The Harlequin duck (*Histrionicus histrionicus*) is designated as a priority habitat species by the State of Washington. This means that this species and its habitat are indicated as a preferentially ranked and, therefore qualifies for management and preservation by state wildlife officials (Schirato 1994). However, because of a lack of information about certain critical aspects of this species' habits in Washington, there is a need for further studies. The intention of this paper is to summarize the phenology (life history), reproductive and survival rates of the Harlequin duck, and based on information cited in the literature, examine the impact of streamflow and invertebrate density cycles on distribution. This information will be addressed in concert with the influence of human activity on the Harlequin duck's breeding grounds and the resulting implications for management practices and conservation.

The phenology, reproductive and survival rates of the Harlequin will be discussed according to the most current literature available for the Pacific Northwest population. This species occupies a unique position as an indicator species and a link between the coast and the mountain streams (Chadwick 1993). This creates an advantage for this duck in the management of wildlife because of a traditionally specialized focus on species that use a range of sensitive habitats. The ecological dependency of the Harlequin on the components of its anadromous life cycle obliges us to fully understanding and evaluate the coastal and riparian habitat components essential for its persistence over time (Ruggiero, Holthausen, Marcot, Aubry, Thomas and Meslow 1988).

Distribution and Appearance

In the state of Washington the maritime distribution of Harlequins includes northern Puget Sound, northern Hood Canal, the Straight of Juan de Fuca, the San Juan Islands, and the outer coast. Interior distribution in the state includes the Olympic, Cascade, Blue and Selkirk Mountains (Gaines 1993). The interior U.S. distribution of the breeding Western population outside of Washington include Oregon (39 streams), Idaho (35 streams), Montana (40 streams) and Wyoming (19 streams) (Status Report 1993).

The appearance of the Harlequin duck is as unusual and enigmatic as its anadromous life cycle. Linnaeus is responsible for the use of Harlequin as the common name that is used throughout this text and in nearly all other literature on this subject. This colorful descriptor indicates how influential the nuptial plumage of the male is to the image we have of this energetic little bird (Friederici 1996). The female and the juvenile birds have much duller plumage and are very similar to each other. The juvenile males do not have full nuptial plumage until their second summer (Status 1993).

All plumage colorations and patterns are cryptic enough to obscure the shape of the bird and to blend its movements into the waves and riffles of the habitat where it can be found (Figure 1). The males have a blue-grey foundation with a burnt sienna patch posterially beneath each wing and a same color strip near the crown. The most striking feature of their plumage is the intermittent distribution of white dots, dashes and commas, most of which is bordered by black that melts unnoticeably into the blue-grey background. The females and juveniles are a dull brown with three indistinct white spots on the head.

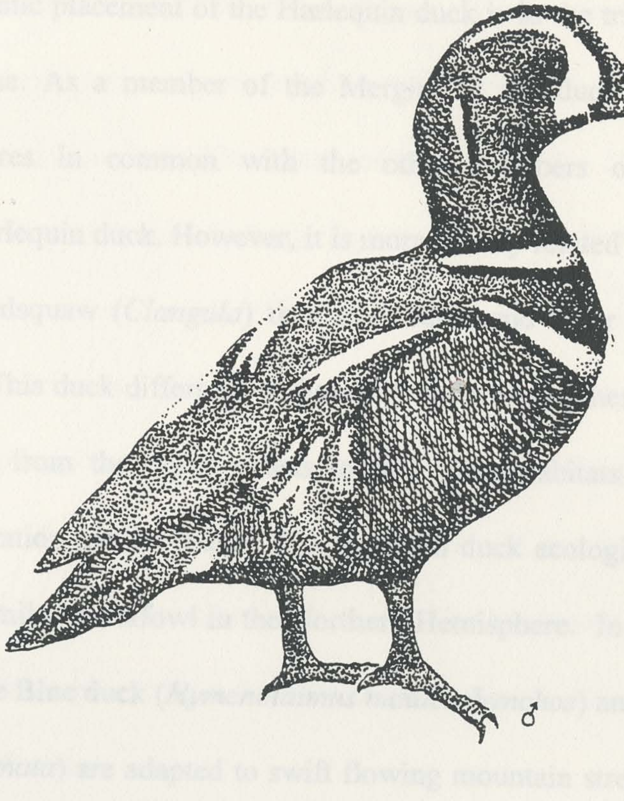

Figure 1. The Harlequin Duck (*Histrionicus histrionicus*).

Taxonomy And Evolution

The taxonomic placement of the Harlequin duck is in the tribe Mergini in the family Anatidae. As a member of the Mergini or sea duck tribe, several evolutionary features in common with the other members of this group characterize the Harlequin duck. However, it is more closely related to the Scoters (*Melanitta*) and Oldsquaw (*Clangula*) than the Eiders and other diving ducks (Johnsgard 1960). This duck differs most distinctly from these other genera in its breeding migration from the ocean coasts to fast water habitats in mountain streams. This migration pattern makes the Harlequin duck ecologically unique. There is no other similar waterfowl in the Northern Hemisphere. In the Southern Hemisphere only the Blue duck (*Hymenolaimus malacorhynchos*) and the Torrent duck (*Mergaetta armata*) are adapted to swift flowing mountain streams (Kuchel 1977). However, they do not lead an anadromous life as the Harlequins do (Cassirer 1991).

The Harlequin's fossil history is recorded as early as the Pleistocene Era (California, Alaska, and Sweden) (USFWS 1994). They are considered a monotypic species among a diverse collection of diving waterfowl, with an equivocal evolutionary history based mostly on reproductive behavior and esophageal physiognomy (Johnsgard 1960). They are thought to have evolved in the western part of their population distribution and later migrated eastward. This theory is based on the number of ducks that occur regionally (Turbak 1997).

Population Size, Distribution And Status

The Harlequin duck population has a disjunct, Nearctic frequency (Figure 2) with the greatest population concentrated in the northern Pacific and smaller populations located in Iceland, Greenland and northeastern North America (Vermeer 1983). These populations range in size from less than five hundred breeding pairs on the Atlantic coast of North America to close to one million individuals observed wintering in the Pacific off the Coast of Alaska. Iceland and Greenland each have approximately ten thousand birds determining the breeding populations (Breault & Savart 1991). The distribution of the Harlequin duck expands in the spring and summer when pairs travel inland to breed on coastal and interior streams. Washington State is home to the largest population of Harlequin ducks in the lower 48 states.

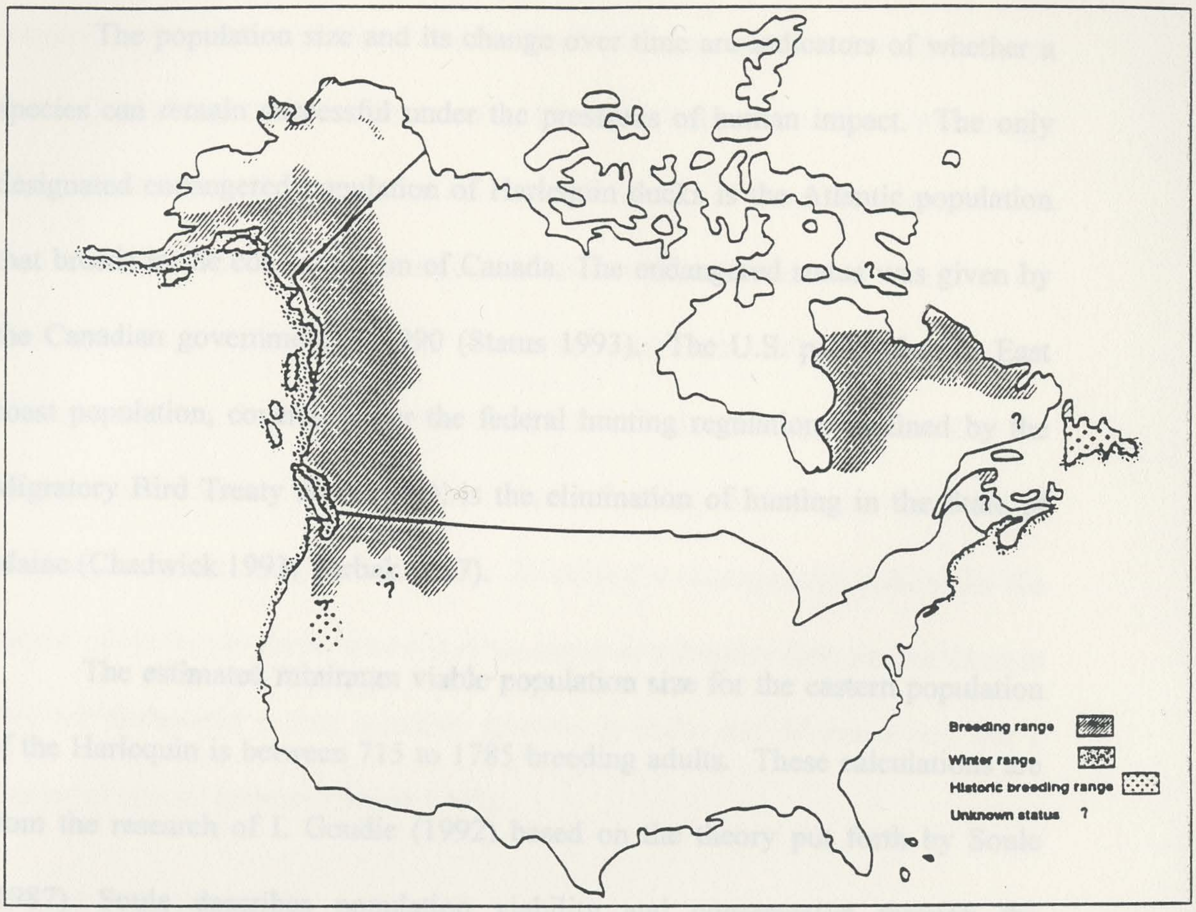

Figure 2. Distribution of Harlequin ducks in North America. 1993. Breeding status is unknown on Baffin Island. New Brunswick and Quebec north of the Gulf of St. Lawrence in the Atlantic population. Status is unknown in the Blue Mountains of Oregon and Washington. the southern Cascades of Oregon and many areas of western Canada and Alaska in the Pacific population (Status 1993).

The population size and its change over time are indicators of whether a species can remain successful under the pressures of human impact. The only designated endangered population of Harlequin ducks is the Atlantic population that breeds in the coastal region of Canada. The endangered status was given by the Canadian government in 1990 (Status 1993). The U.S. policy for the East coast population, covered under the federal hunting regulations outlined by the Migratory Bird Treaty Act (1918), is the elimination of hunting in the State of Maine (Chadwick 1993; Turbak 1997).

The estimated minimum viable population size for the eastern population of the Harlequin is between 715 to 1785 breeding adults. These calculations are from the research of I. Goudie (1992) based on the theory put forth by Soule (1987). Soule describes population viability and conservation through the relationship between population lifetimes and the various conditions that can influence those lifetimes, including stochastic events, abundance, distribution, habitat availability and abundance of the species. The Harlequin appears to be retracting from its usual historical distribution along the breeding grounds (Genter 1993). Although it has suffered less from the impact of human disturbance because of the selection of remote areas to winter and breed, there is cause for concern as the expansion of land use increases.

The United States Forest Service classifies the Harlequin as a Sensitive Species, incorporating specific management policy in areas where they occur for

Region 1 (Montana, northern Idaho, North Dakota, and northwestern South Dakota) and Region 4 (southern Idaho, Nevada, Utah, and western Wyoming). The United States Department of the Interior-Bureau of Land Management has also developed streamside management zones that include concern for the Harlequin duck (USFWS 1994). However under the 1976 National Forest Management Act, the Forest Service classification has more legal bearing than the management policies of the BLM (Clark, Reading and Clarke eds. 1994). Washington is the only state that has developed a management policy for the habitat of Harlequin ducks where it is managed as a Priority Species. In Oregon they are designated a state sensitive species; in Idaho and Montana they are a species of special concern (Status 1993).

Habitat Utilization

The Harlequin selects wintering and breeding habitats by a combination of availability of specific habitat requirements and site fidelity (Bengtson 1972; 1966; Gaines 1993; Gardarsson & Einarsson 1994). These birds migrate mostly in pairs to their natal breeding grounds during the late spring and early summer months. Males return to their wintering grounds starting in June while females and juveniles migrate in September. They winter on the coasts of the region where they live and breed mostly on first-, second-, and third-order streams (Bengtson 1972; Genter 1993). This movement back to the coast is done in order to molt in a safe and productive habitat. The following sections will describe the coastal and riparian habitats used by Harlequin ducks and their migration timing.

Wintering Habitat

The Harlequin duck is a sea duck and spends the majority of its life foraging on the rugged coasts of its range. Males spend as much as ten months of the year on their wintering grounds (Fleishner 1983). Although a sea duck, the Harlequin has adapted a cycle in its life for breeding on mountain streams. However, the capacity of the streams to support the ducks is ephemeral, requiring the ducks to return to the sea. There are many factors that contribute to the distribution and composition of Harlequin duck populations along its wintering habitat. These include food availability, site fidelity and safety from predation (Salomonsen 1968).

Food and Feeding

Harlequins are social when wintering and congregate in flocks discreetly distributed over their selected range. They are adept divers and prefer to stay near shore over gradually sloping cobble or cobble/rock substrate in order to feed (Bengtson 1966). Hirsch's (1980) research shows a preference by Harlequins on the inland waters of Washington for gradually sloping, *sandy* substrate featuring an eelgrass ecosystem. Further habitat parameters include a preference for low depths and short distances from the shore.

Harlequins exhibit distinct habitat preferences along the coast of Washington, and although no quantitative data on diet has been collected, possible sources of food are crustaceans including small crabs (*Hemigrapsus* spp.), isopods had no conspicuous benefits over nearby sites of comparable value leading to the conclusion, based on the literature, that food availability is the cause for this arrangement of dispersal. The flocks of ducks vary considerably in size; they are in the hundreds along the coast of Washington and reach the thousands along the Aleutian Islands of Alaska (Breault & Savard 1991; USFWS 1994; Friederici 1996).

The Harlequin duck has a complex phenology. This bird is slow to reach sexual maturity, the clutches are small, there is low recruitment annually, and they are long-lived, which makes them a K-selected species with populations comprised primarily of adults and sensitive to any increase in mortalities (Goudie 1996). As a result of this reproductive strategy that leads to a population composed mostly of adults, there are questions about the wintering ecology and survival of the juveniles (Chadwick 1992, Proceedings; Fleishner 1983). Observations indicate that discreet congregations of age classes characterize the winter gathering activities of Harlequins. Greater quantitative data on winter ecology and survival of juveniles would contribute considerably to current knowledge.

Breeding Habitat

Like the salmon, the Harlequin ascends rivers and return to its natal stream to reproduce. In Washington and the other northwest states of its territory the Harlequin breeds mostly on first-, second-, and third-order streams (Bengtson

1972; Genter 1993). Their migration begins near the end of March and beginning of April in Washington, and is influenced by environmental factors (Kuchel 1977). The most important characteristics of the stream habitat are food availability, nesting and loafing sites, slow water areas for young broods, and isolation (Kuchel 1977). Many physical and morphological features of the riparian area can be identified for promoting these important characteristics including stream gradient, width, depth, substrate, velocity, turbidity, bank vegetation, woody debris, and sinuosity (Bengtson 1972; Beschta and Platts 1986; Stanford and Ward 1992; Status 1993).

The Harlequin may leave the coast, but the turbulent waters that it does so well in are also selected for in its stream habitat (Bengtson 1966; 1972; Inglis, Lazarus and Torrence 1989; Genter 1993). The composition of the stream includes riffles, pocket water and runs, cobble and boulder substrate, trees and shrubs (Gaines 1993). The streams are usually straight and confined by the geomorphic surface of the river valley (Gaines 1993; Gregory 1991). All of these factors vary regionally in providing acceptable breeding habitat (Bengtson 1966; 1972; Cassirer & Groves 1991; Gaines 1993; Jarvis & Bruner 1996; Kuchel 1977).

Food and Feeding

Harlequin ducks feed almost exclusively on animal matter, but do not specialize in their selection of prey species (Bengtson 1966; 1972; Bengtson &

Ulfstrand 1971; Inglis et al. 1987; Kuchel 1977). Their food base switches according to whether they are in a marine or freshwater environment. Keeping in mind the evolutionary theory for r and K-selected species, this limited food base gives some evidence for the following adaptations: harlequins breed relatively late, the females' lay smaller clutches of larger eggs, the young fledge quickly and the males depart soon after the incubation phase begins (Bengtson 1966). In the freshwater environment, the Harlequin duck feeds almost exclusively on insects. The emergence of insect larvae impacts the timing of migration, the distribution and productivity of these birds along the stream during their breeding and nesting cycle (Bengtson 1972; Bengtson & Ulfstrand 1971).

Several sources describe the Harlequin as an opportunistic feeder of high protein foods, almost exclusively benthic invertebrate larvae (Bengtson 1966; 1972; Bengtson & Ulfstrand 1971; Gardarsson & Einarsson 1994; Inglis et al. 1987). Studies in Iceland show that the blackfly (Dipteran) larvae are their primary source, with up to 99% of stomach contents containing this species (Bengtson 1972). Other studies indicate predation of Plecopterans (stonefly larvae) and Ephemeropterans (mayfly larvae) where these species are dominant/abundant (Wallen 1987). Wallen (1987) observed the casings of caddisfly (Tricopteran) larvae in fecal material in his study of Harlequin duck ecology in Grand Teton National Park. It has yet to be determined what the Harlequin eats on the streams of Washington.

Courtship

Outside of feeding, the most important activity for survival of a species is reproduction. Reproduction for this species involves ritualized courtship displays, pairing, migration to the breeding grounds, copulation, nesting and brood rearing. Their breeding behavior has few visual components because of the difficulty of displaying on turbulent waters. The reduced use of vocal communication has evolved because of the constant background noise that dominates their white water habitat (Inglis et al. 1989). Courtship displays begin on the coast preceding the breeding migration to natal streams and the Harlequin continues to perform courtship displays and copulate on the breeding grounds (Genter 1993).

Migration

Site fidelity or philopatry is well developed in the Harlequin and has been recorded in both sexes. The Harlequins form a pair bond and are known to return to nearly exact locations (ex.: same loafing sites) each year (Bengtson 1972; Crowley 1993; Gaines 1993; Goudie 1996; Kuchel 1977). The vast majority of sexually mature Harlequins are paired before entering the riparian system (Genter 1993). Unpaired sexually mature males also migrate to the breeding grounds. Aldrich (1983) describes this as a mechanism for stimulating courtship behavior and providing further opportunity to breed if a paired male is killed on the stream or during migration. Unpaired females have also been documented on the breeding grounds. Researchers have concluded that these birds are underaged nonbreeders prospecting for next season or birds that have lost their brood (Wallen 1987; Cassirer & Groves 1991)

There are no conclusive reports on how Harlequins migrate to and from the breeding grounds. It is certain that whenever possible they fly low over the active river channel paralleling each bend. Yet, birds have been documented outside the riparian corridor of final breeding destinations (Cassirer & Groves 1991). Furthermore, the populations that breed east of mountain divides must fly overland to arrive there.

Behavior

Kuchel (1977) divides the breeding season into two periods, courtship and nesting, and brood rearing. The times of these events differ regionally but the duration is relatively stable. Courtship begins on the coastal waters where the Harlequins begin pair formation. Furthermore, characteristic duck breeding behaviors, such as head nodding and rushing, are sparse (Kuchel 1977; Inglis et al. 1989). The males are not territorial but defend an area around the female (Inglis et al. 1989; Bengtson 1972). The females' prone position when soliciting her mate is a distinguishing behavior of the Mergini tribe (Inglis et al. 1989). However, the male Harlequin's act of pecking the back of the female's neck differentiates the Harlequin within this tribe and Inglis et al. (1989) give this as evidence of a primitive evolutionary link to the Cairini tribe because of its resemblance to the Wood Duck's (*Aix sponsa*) behavior.

Nesting

Until nesting begins, the females stay within a few meters of the stream (Inglis et al. 1989). Once nest prospecting begins, the females will spend hours walking on shore or will fly to search for cavities (Bengtson 1966). The requirements for nesting vary regionally and nests are found in a variety of sites: ground, ledges, snags, cavities and log jam debris (Breault & Savard 1991; Genter 1993; Status 1993).

Breault and Savard (1991) suggest that nesting in short coastal creeks contribute greatly to annual Harlequin duck production. This is because of the availability of marine invertebrates, which are far more numerous than freshwater invertebrates and closer to nesting and brood rearing areas than if the families were significantly farther up stream. In contrast, Crowley (1993) who studied the Harlequins breeding in eastern Prince William Sound, stated that the productivity of coastal breeding Harlequins is similar to that of inland breeders.

An interesting aspect of the Harlequins' nesting behavior is that of timing. The late nesting time of the Harlequin duck corresponds to the condition of the breeding habitat, the food supply and the lack of possibilities for renesting (Bengtson 1966). The timing of nesting (Glacier National Park, Montana) is correlated to spring stream runoff and food availability (Kuchel 1977; Bengtson and Ulfstrand 1971). Stream runoff has a devastating effect on Harlequin nest sites if the sites are selected too early (Kuchel 1977; Wallen 1987). In variation in productivity among the western coterminous United States is said to be primarily the difference among the success of the broods (Genter 1993).

Mortality is highest within the first two weeks after hatching (Bengtson 1972; Kuchel 1977). The ducklings' survival is based on the availability of food and their ability to escape predation (Kuchel 1977). The architecture and complexity of the stream provides the necessary food supplies and refugia for adequate survival to fledging (Cassirer 1991; Genter 1993; Wallen 1987).

The reproductive cycle is complete when the females and their young travel back to the coast. The timid nature of this bird makes it difficult to observe the downstream migration of the females and juveniles. This migration of females and juveniles begins as a downward stream expansion of home range (Kuchel 1977). There is some conflict in the literature about whether or not the hen escorts her brood. The majority of the literature supports the theory that the females lead their young to sea (Kuchel 1977; Breault & Savard 1991; Inglis et al. 1989). However, there remains strong evidence for the abandonment of broods by females in order to molt (Cassirer & Groves 1991). The reason for this variance perhaps lies in the distance needed to travel. Females closer to the marine environment may stay longer on the stream with their broods.

CHAPTER THREE: HABITAT CHARACTERIZATION

Introduction

The Harlequin duck spends the breeding season on the rivers and streams of the Olympic Peninsula. The basis of this paper is to focus on some aspects of this species activity and occurrence during the breeding season on the rivers and streams. The two issues that are raised involve the timing of nest initiation and its relationship to seasonal stream flow activity and the appearance of this species on streams that have varying benthic invertebrate densities. This chapter goes into detail about riparian ecology, habitat requirements and duck production in order to build a foundation for the conservation, management and study recommendations that conclude this paper.

Awareness of the riparian system and the following specific habitat characteristics and requirements will allow for a better judgment of the importance of stream flow events to the Harlequin duck on the Olympic Peninsula. This chapter addresses the dimensions of the lotic habitat. In the section titled Riparian Ecology, benthic invertebrates and bioassessment are discussed. Next the section titled Habitat Requirements, explains a theory of habitat selection and lists observed specific habitat features. The section titled Harlequin Duck Production details the breeding population of the Olympic Peninsula and discusses habitat features necessary for brood rearing.

Riparian Ecology

Stanford and Ward (1992) characterize rivers as multi-dimensional environments that connect hydrological and biological processes. The dimensions are upstream-downstream, channel-hyporheic (groundwater), and channel-floodplain (riparian) zones, which are differentially acted upon over time. The river is an energy transfer system, the structure and process of which is determined by its interface with adjoining ecosystems (Gregory 1991).

The availability of energy sources to the Harlequin from the abundance of the lotic ecosystem is crucial to its productivity. The system should be as undisturbed and unaltered from the headwaters to the estuary as possible in order to provide a complete delivery of organic material. This organic material is consumed, abraded, fragmented, leached and released by a variety of mechanisms, not the least of which is the diversity of macroinvertebrates that provide the food supply for the Harlequin (Gregory 1991).

Channel morphology and overland flow are essential to the function of a lotic ecosystem. If this morphology is altered or manipulated in any way, it can be devastating to the survival of the Harlequin. The river channel is of utmost importance to them as its geomorphic surfaces create physical patterns that help define the diversity of adjacent plant communities and occurrence of aquatic invertebrates (Gregory 1991).

Overland flow is determined by the amount of water not absorbed, evaporated or transpired from net precipitation in the form of snowmelt and rainfall. If the amount of absorption by soil surface and evapotranspiration by plant communities is altered, it will seriously impact this part of the system to increase overland flow (Hewlett and Nutter 1969). Human activity or natural disaster can cause a significant change in normal overland flow and the result could impair the Harlequins' ability to feed, raise their broods and consequently survive. The increase in overland stream flow for the purposes of this paper is linked to the survival of nests and young ducks. A comparison is made between spring stream runoff and the timing of nest initiation within and between years. The purpose of briefly discussing overland flow is an effort to highlight the potential influence of outside forces upon a critical component of Harlequin duck habitat .

Benthic Invertebrates

The amount of literature available on the subject of Harlequin diet on the breeding streams is meager. Furthermore, the information available is moderately inconclusive because of its statistical limitations. Nonetheless, it can be stated that these birds are opportunistic feeders of high protein food types and that likely sources are the dominant or most abundant aquatic insect larvae. The species of aquatic insects observed in the studies done in comparative proximity to the Western Washington population could have bearing on future studies and the implementation of management practices.

Wallen (1987) sampled known Harlequin streams and insect remains from Harlequin gizzard contents and fecal components in Death Canyon, Grand Teton National Park. He identified five genera of Plecopterans, nine genera of Ephemeropterans, seven genera of Trichopterans, five families of Diptera and two families of Coleoptera from the kick net survey at feeding sites in Death Canyon. Ephemeropteran remains were identified in the gizzard (*Heptagenia* sp.). Fecal components included the casings of Trichoptera (*Glossoma* sp.) and the exoskeletal and gill remains of Plecoptera (*Megarcys* sp. and/or *Isoperla* sp.), Ephemeroptera (*Drenella* spp.) and Trichoptera (*Parapsych*e sp.). Another study done in Wyoming found the stomach contents of two birds contained up to 90% Plecopterans (Cottam 1939). In Oregon, an observation of high abundance of Trichopterans along the streams where Harlequins were captured and studied has been indicated as a food resource (Jarvis 1996).

Bioassessment

Biological assessment (bioassessment) is the technique used to quantify characteristics of the ecosystem and to determine environmental quality through the use of reference locations and overall analysis and comparison. Bioassessment as mandated by the 1972 Federal Clean Water Act (sec. 101) focuses on the quantity and diversity of macroinvertebrates. Considering the influence of food availability and distribution on the life cycle and physiology of the Harlequin duck, the data collected for the bioassessment research from the Washington State Department of Ecology has some potential for understanding this species.

For this study invertebrate density data in pool and riffle habitats for the years of 1994 and 1995 are used. This data can be useful in the evaluation of one or more levels of an ecosystem. For the Harlequin, these data are not precise enough to show local species abundances available as a food resource. However, these data are used to establish a correlation between the appearance of Harlequins on streams and invertebrate densities thus providing a statistically viable conclusion about the ecology of the Harlequin duck on the Olympic Peninsula.

Habitat Requirements

The close association of Harlequins with specific habitat components should determine management priorities in the effort to allow for the persistence of this species (Cassirer & Groves 1991). The selection of habitat is hierarchical. That is, in general the preference of habitat type precedes the selection of homerange. However, further assumptions must not be overlooked, such as the constraint of habitat selection, the role of critical environments and the interpretation of preference. Dependency perhaps is not a useful measurement of the state of nature, but a useful concept or framework upon which to arrange our understanding of discreet populations and habitats (Ruggiero et al. 1988). Furthermore, the availability of optimal conditions throughout the range may not be possible to achieve, but through careful management there is the potential to secure acceptable habitat (Hochbaum 1946).

The population of Harlequin ducks breeding on the Olympic Peninsula is considered an ecotypic variation. As an ecotype, they are adapted to local conditions of the coastal mountain range and differ from other distinct breeding populations in their reproductive timing and selection of other habitat components such as food types (Ruggiero et al. 1988).

<u>Specific Requirements</u>

The habitat characteristics that define the availibility of food include swiftly flowing water, substrate type, stream gradient, reticulate canyons and vegetation. Habitat features that improve brood habitat and increase the value of specific sites are slow water areas, overhanging vegetation, undercut banks and woody debris. Threats include predation, catastrophic flooding events, hunting, and human recreational and commercial activities (Cassirer 1991; Clarkson 1992; Genter 1993; Goudie 1996; Wallen 1987; Status 1993).

HARLEQUIN DUCK PRODUCTION

Studies of Harlequins on the Olympic Peninsula have documented them on 19 river systems. The densities that were observed did not exceed two pairs per kilometer, with a minimum estimate of approximately 300 birds. The Harlequin selects for a distinct range of stream gradient (1-7%), and are not found on the lower portions of the Western streams. In predicting the breeding habitat of Harlequins, the most reliable feature appears to be stream morphology (Schirato & Sharpe 1992).

The stream orders that Harlequin ducks have most frequently been found on in the contiguous United States are those most likely to be impacted by human land-use and recreational activities (Beschta & Platts 1986). Much of the human land-use activities involve clearing vegetation along the streams. This vegetation causes diurnal fluctuation of stream flow through evapotranspiration (Hewlett & Nutter 1969). Harlequins favor certain depths of rapids and waterfalls and feed in a two-peak pattern corresponding to these depth preferences. The alteration of stream vegetation could have an impact on their feeding success and food availability (Bengtson 1966; 1972).

Turbulent, whitewater streams are a high priority for Harlequin ducks because of the increased availability of insect larvae that favor these habitats over muddier calmer waters (Genter 1993; Inglis, et al. 1989). The complexity of the stream habitat composed of riffles, runs and pools, contributes to the health of these communities by dispersing energy and oxygenating the water (Beschta & Platts 1986).

The lives of Harlequins on the streams are measured as productivity, or the ability to survive and reproduce. The survival of adult females is important to the stability of the Harlequin population, since it is their contribution as producers that is crucial to population endurance. Population statistics in Washington are calculated from the winter flight surveys, from band returns and resightings and by occasional stream surveys.

Summary Statistics for Washington State

It is estimated that there are at least 152 pairs of Harlequins nesting on the Olympic Peninsula with densities along the streams of 0.01-1.6 pairs / km. The stability of this population is not known. Productivity measurements available are brood sizes averaging 4.4 (N = 35) in 1991 and 3.3 (N = 24) in 1992. Radiotracking efforts to assess mortality showed none after 30-45 days (Schirato 1994). However, enough work has not been done in this area to develop meaningful results for the state of Washington. Nest sites were located most often on mid-islands of channels where predation of eggs by river otters and black bears were observed. Three of twelve birds banded and radio tagged on the stream in 1992 returned the next year. The harvest records are negligible (Schirato 1994).

Brood Requirements

Pair density can be correlated to some available habitat components. Cassirer (1991) study of the Harlequin breeding population in Idaho drew the following conclusions about the selection of habitat based on brood requirements. Overall requirements for production by Harlequins are vague, and because of the nature of philopatry, annual population densities reflect the production of previous years.

Components of good brood habitat are smaller streams, slower water, more woody debris, vegetative overhang and bank undercut. This list is based on the comparison of streams with higher pair densities to those with lower pair densities. Mature forest overstory was correlated to the selection of brood habitat but this is thought to be because of the low human impact and pristine nature of the habitat and not because of the availability of vegetative features (Cassirer & Groves 1991). Harlequins are highly adaptable throughout their breeding range and very few characteristics remain constant as predictors of Harlequin duck occurrences. Those that do are repeatedly cited as the variables influencing the distribution and density of benthic invertebrates.

This collection of Harlequin duck knowledge is valuable, but of limited use because there are too many variables not available for the characterization of the Washington population. What can be said about and what is observed from a few discreet populations cannot be fully extrapolated for use in management of separate populations responding to disparate food sources, habitat components and environmental factors.

Currently general ecological features are projected upon distinct ecotypes to devise and implement management decisions. The information presented in this paper is the comparison of local hydrological events to nesting activity and invertebrate densities to occurrence. The intent of the author is to contribute to more effective management of the Harlequin duck on the Olympic Peninsula.

CHAPTER FOUR: NEST INITIATION AND THE ROLE OF STREAM FLOW

COMPARISON OF MEAN NEST INITIATION DATES

Because the Harlequin ducks of the Rocky Mountain breeding area are vulnerable to the peak stream flows of the spring thaw it is the author's intention to determine if there is any similar phenomenon acting upon the breeding population of the Olympic Peninsula. The literature supports the devastating impact that a major flooding can have on nests and young broods in Montana (Bengtson and Ulfstrand 1971; Diamond & Finnegan 1993; Kuchel 1977). It is relevant to know what impact if any there is from increased spring flows from the higher rate of rainfall precipitation observed each year and spring run-off on the Olympic Peninsula.

Two tests are used in this chapter to evaluate if stream flow affects the timing of nesting of Harlequin ducks on the Olympic Peninsula. These statistical comparisons are set up to determine if there is any similarity between the results of increased spring run-off from the Olympic Mountains and the glacially fed streams of the Rocky Mountain habitat.

The first part of this chapter is an examination of stream flow during average years and the year of a flood event. The comparison is made using the grouped mean nest initiation dates of four years compared to the mean nest initiation dates of one year with a notable flood event. The purpose is to acquire preliminary information about the effect of high stream flow on nesting Harlequin ducks.

The second part of this chapter correlates average daily flow data and nest initiation dates. This comparison evaluates average daily stream flow relative to observed dates of nest initiation. The purpose of this correlation is to gain introductory knowledge on the relationship of daily stream flow influx to a range of nest initiation dates in order to evaluate the influence of stream flow on nesting.

Methods

Data of brood size and age (Table 1) was collected from stream surveys (N. Perfido) done in the months May, June and July of the years 1991, 1992, 1993, 1994 and 1996 by observing females with broods. Nest initiation and hatching times were calculated by backdating from the estimated class age of each cohort. Backdating times are based on the chronology of plumage development in juvenile Harlequin ducks from Wallen (1987) that was developed from the work of Gollop and Marshall (1954) for the Mississippi Flyway Council. The rivers surveyed were the Hamma Hamma, Duckabush, Quilcene, Dosewallips, Elwha Dungeness Rivers and Morse Creek.

In order to compare mean nest initiation dates for these times the dates were converted to Julian dates. The data was grouped into all years before 1996 and tested against the data from 1996 when an unusually high spring flood event occured. The null hypothesis is that of no difference between the means of nest initiation timing between the grouped years before 1996 and the year of 1996. The statistical analysis used was a Student's t-test with $\alpha = .05$, a two-tailed distribution and equal variance about the mean.

Date Obs.	Class	Julian date	Est. Hatch	Est. Nest	River	No. of young
6/11/91	Ib	121	6/3/91	5/1/91	Dose	2
6/11/91	Ib	121	6/3/91	5/1/91	Dose	6
8/17/91	IIc	163	7/16/91	6/12/91	Quilcene	4
5/29/92	Ib	108	5/21/92	4/17/92	Ducka	5
6/3/92	Ia	119	5/31/92	4/28/92	Dose	1
5/21/92	midpoint	129	6/4/92	5/8/92	Elwha	eggs -no. unk
7/23/92	III	132	6/14/92	5/11/92	Quilcene	3
6/5/92	(first 1/3)	142	6/24/92	5/21/92	Dungen	eggs -no. unk
6/10/93	<6days	122	6/5/93	5/2/93	Morse Cr.	4
6/10/93	<3days	125	6/8/93	5/5/93	Morse Cr.	2
6/25/94	IIc	111	5/24/94	4/21/94	H.Hamma	4
6/7/94	Ic	112	5/26/94	4/22/94	Ducka	5
6/16/94	IIa	116	5/29/94	4/26/94	Quilcene	1
6/17/94	IIa	117	5/30/94	4/27/94	H.Hamma	5
6/17/94	IIa	117	5/30/94	4/27/94	H.Hamma	4
6/25/94	IIa	125	6/7/94	5/5/94	H.Hamma	2
6/14/94	Ia	129	6/11/94	5/9/94	Ducka	7
6/7/94	midpoint	139	6/21/94	5/19/94	Ducka	8 eggs
6/23/96	III	103	5/15/96	4/12/96	Morse Cr.	4
7/18/96	III	128	6/9/96	5/7/96	Morse Cr.	4
7/10/96	IIb	134	6/15/96	5/13/96	Ducka	2
7/11/96	IIa	143	6/23/96	5/22/96	H.Hamma	2
7/24/96	IIb-IIc	146	6/27/96	5/25/96	Ducka	4
7/24/96	IIb	148	6/29/96	5/27/96	H.Hamma	1
7/11/96	Ib-Ic	151	7/1/96	5/30/96	H.Hamma	3
7/20/96	IIa	151	7/2/96	5/30/96	H.Hamma	2
7/20/96	IIa	151	7/2/96	5/30/96	H.Hamma	3
7/28/96	IIa-IIb	156	7/6/96	6/4/96	Ducka	4
7/24/96	Ib	165	7/16/96	6/13/96	Ducka	1

Table 1. Stream survey data for 1991-1994 and 1996 (N. Perfido 1997)

Results

The comparison between nest initiation dates resulted in no difference ($p < .01$). There is no discernible effect from the higher spring stream flow of 1996 compared to the previous years on the timing of nest initiation of Harlequin ducks on the Olympic Peninsula.

Discussion

The Harlequin duck has a high juvenile survival on the streams where they have been observed (Goudie 1996). For the years compared in this paper, streamflow did not influence nest initiation timing. This indicates that the river systems of the Olympic Peninsula characterized by precipitation do not threaten nesting Harlequins with devastating flood events compared to the river systems of the Rocky Mountains dominated by snow melt runoff.

This comparison of mean nest initiation times is at best weak. There are no more than five data points for one river in one year (Hamma Hamma 1996). For the purposes of this paper the rivers were grouped. The year of 1993 was left out because there were only two observations of very young broods that had nest initiation dates only three days apart, providing a very narrow range and a weak set of data.

FLOW DATA CORRELATED TO THE TIMING OF NEST INITIATION

Average daily flow data was acquired from the USGS for the purposes of comparing flow trends to the nesting activities of the Harlequin duck on the Olympic Peninsula (Table 2). This is another way to observe the influence of stream flow on the nest initiation of the Harlequin duck. This answers basically the same question as before but defines stream flow distinctly. Flash flooding is a surprise event whereas above average flow over longer periods of time might be responded to through behavioral modification.

Methods

The range of nest initiation times for the years 1991, 1992, 1994 and 1996 cover the months of April, May and June. The data points for Morse Creek in 1993 were left out because of the limited time span. An index was developed as percentages for each river for each year. The rivers (Duckabush, Hoh, Queets and Quinault) are indexed to reduce the skewing of data of the three high flow rivers against the much lower flowing Duckabush River.

Date	Julian #	Date	Julian #	Date	Julian #	Date	Julian #	
5/1/91	121	4/17/92	108	4/21/94	111	4/12/96	103	
5/2/91	122	4/18/92	109	4/22/94	112	4/13/96	104	
5/3/91	123	4/19/92	110	4/23/94	113	4/14/96	105	
5/4/91	124	4/20/92	111	4/24/94	114	4/15/96	106	
5/5/91	125	4/21/92	112	4/25/94	115	4/16/96	107	
5/6/91	126	4/22/92	113	4/26/94	116	4/17/96	108	
5/7/91	127	4/23/92	114	4/27/94	117	4/18/96	109	
5/8/91	128	4/24/92	115	4/28/94	118	4/19/96	110	
5/9/91	129	4/25/92	116	4/29/94	119	4/20/96	111	
5/10/91	130	4/26/92	117	4/30/94	120	4/21/96	112	
5/11/91	131	4/27/92	118	5/1/94	121	4/22/96	113	
5/12/91	132	4/28/92	119	5/2/94	122	4/23/96	114	
5/13/91	133	4/29/92	120	5/3/94	123	4/24/96	115	
5/14/91	134	4/30/92	121	5/4/94	124	4/25/96	116	
5/15/91	135	5/1/92	122	5/5/94	125	4/26/96	117	
5/16/91	136	5/2/92	123	5/6/94	126	4/27/96	118	
5/17/91	137	5/3/92	124	5/7/94	127	4/28/96	119	
5/18/91	138	5/4/92	125	5/8/94	128	4/29/96	120	
5/19/91	139	5/5/92	126	5/9/94	129	4/30/96	121	
5/20/91	140	5/6/92	127	5/10/94	130	5/1/96	122	
5/21/91	141	5/7/92	128	5/11/94	131	5/2/96	123	
5/22/91	142	5/8/92	129	5/12/94	132	5/3/96	124	
5/23/91	143	5/9/92	130	5/13/94	133	5/4/96	125	
5/24/91	144	5/10/92	131	5/14/94	134	5/5/96	126	
5/25/91	145	5/11/92	132	5/15/94	135	5/6/96	127	
5/26/91	146	5/12/92	133	5/16/94	136	5/7/96	128	
5/27/91	147	5/13/92	134	5/17/94	137	5/8/96	129	
5/28/91	148	5/14/92	135	5/18/94	138	5/9/96	130	
5/29/91	149	5/15/92	136	5/19/94	139	5/10/96	131	
5/30/91	150	5/16/92	137			5/11/96	132	
5/31/91	151	5/17/92	138			5/12/96	133	
6/1/91	152	5/18/92	139			5/13/96	134	
6/2/91	153	5/19/92	140			5/14/96	135	
6/3/91	154	5/20/92	141			5/15/96	136	
6/4/91	155	5/21/92	142			5/16/96	137	
6/5/91	156					5/17/96	138	
6/6/91	157					5/18/96	139	
6/7/91	158					5/19/96	140	
6/8/91	159					5/20/96	141	
6/9/91	160					5/21/96	142	
6/10/91	161					5/22/96	143	
6/11/91	162					5/23/96	144	
6/12/91	163					5/24/96	145	
						5/25/96	146	
						5/26/96	147	
						5/27/96	148	
						5/28/96	149	
						5/29/96	150	
						5/30/96	151	
						5/31/96	152	
						6/1/96	153	
						6/2/96	154	
						6/3/96	155	
						6/4/96	156	
						6/5/96	157	
						6/6/96	158	
						6/7/96	159	
						6/8/96	160	
						6/9/96	161	
						6/10/96	162	
						6/11/96	163	
						6/12/96	164	
						6/13/96	165	
43		35		29		63		Number of days
5/22/91	142	5/4/92	125	5/4/94	125	5/13/96	134	Mean

Table 2. Range of nest initiation dates and corresponding Julian dates for 1991, 1992, 1994 and 1996 (N. Perfido 1997).

The indexed columns of data were correlated with nest initiation dates transformed into a binary code of, 0 = not nesting and 1 = nesting. The correlation measures the relationship between two sets of data scaled to be independent of the unit of measure. The correlation is the covariance of the two data sets divided by the product of their standard deviation (Microsoft Excel 1994).

Results

There is little correlation between the dates of nest initiation and the daily stream flow of these rivers ($\alpha = 0.05$). The following are the correlation coefficients by year; 1991: $r^2 = -0.10$; 1992: $r^2 = 0.09$; 1994: $r^2 = -0.05$; 1996: $r^2 = 0.12$.

Discussion

There were no highly unusual daily flow events that can be correlated to the range of nesting times during the years that were compared. The variability in the signs of the correlation coefficients indicates that not only are the data weakly correlated, but that there are other key variables influencing nest initiation timing. This indicates the sheltered nature of the riparian hydrological regime on the Olympic Peninsula. In the management of the resources benefiting the Harlequin duck the breeding grounds used on the Olympic Peninsula appear to be more favorable than the Rocky Mountains that are influenced in the spring, particularly April and May, by snow melt run-off.

The limitations of the data points for the range of nest initiations was again a problem in the strength of the conclusions that can be drawn from this study.

More data points could provide for a better relationship between the average daily stream flow and the timing of nesting activity.

streams without Harlequins. The comparison was done for the categories of Pools and Riffles (Tables 3 and 4). The null hypothesis is that there is no difference between the streams with and without Harlequin ducks. A Mann-Whitney test was used with $\alpha = 0.05$, a two-tailed distribution and unequal variance.

Stream Name	Sample date	Bugs/M^2	RANK	Habitat type	Stream ID	
SALMON R.	02-Aug-94	3942.40	10	POOL	WA837S	**with**
DUCKABUSH R.	04-Oct-94	4682.50	7	POOL	WA858S	
NF SATSOP R.	29-Aug-95	2906.40	13	POOL	WA017S	
NF SATSOP R.	31-Aug-95	9065.00	3	POOL	WA016S	
PYSHT CR.	21-Jul-94	1818.00	17	POOL	WA861S	**without**
TRB QUINAULT R.	28-Jul-94	4063.50	8	POOL	WA840S	
WF HOQUIAM R.	03-Aug-94	5382.10	5	POOL	WA850S	
ZIEGLER CR.	11-Aug-94	3713.70	11	POOL	WA838S	
CAMP CR.	21-Sep-94	1275.60	20	POOL	WA848S	
TRB QUINAULT R.	19-Oct-94	2357.40	27	POOL	WA840S	
PYSHT CR.	20-Oct-94	9647.50	2	POOL	WA861S	
COOK CR.	12-Jul-95	5782.40	4	POOL	WA011S	
COAL CR.	01-Aug-95	1614.60	18	POOL	WA007S	
WEST TWIN CR.	02-Aug-95	3002.00	12	POOL	WA009S	
TRB QUINAULT R.	03-Aug-95	15379.40	1	POOL	WA840S	
NF CROOKED CR.	08-Aug-95	452.10	25	POOL	WA003S	
TRB WF DICKEY	09-Aug-95	915.00	22	POOL	WA004S	
TRB CLOQUALLUM	10-Aug-95	5220.70	6	POOL	WA018S	
PYSHT CR.	17-Aug-95	1851.50	16	POOL	WA861S	
SF SKOKOMISH R.	22-Aug-95	3991.70	9	POOL	WA028S	
PINE CR.	24-Aug-95	457.50	24	POOL	WA029S	
CLOQUALLUM CR.	05-Sep-95	2103.10	15	POOL	WA019S	
NF SALMON R.	26-Sep-95	1383.20	19	POOL	WA089S	
TRB QUINAULT R.	27-Sep-95	601.50	23	POOL	WA840S	
PYSHT CR.	28-Sep-95	947.10	21	POOL	WA861S	

Table 3. Invertebrate density data of pool habitats for 1994 and 1995 (Washington State Department of Ecology).

Stream Name	Sample date	Bugs/M^2	RANK	Habitat type	Stream ID
SALMON R.	02-Aug-94	8547.00	4	RIFFLE	WA837S
DUCKABUSH R.	04-Oct-94	9906.17	3	RIFFLE	WA858S
NF SATSOP R.	29-Aug-95	11265.34	2	RIFFLE	WA017S
NF SATSOP R.	31-Aug-95	12624.51	1	RIFFLE	WA016S
SF PYSHT R.	20-Jul-94	1230.20	23	RIFFLE	WA860S
PYSHT R.	21-Jul-94	3697.50	10	RIFFLE	WA861S
TRB QUINAULT R.	28-Jul-94	3950.50	9	RIFFLE	WA840S
WF HOQUIAM R.	03-Aug-94	1639.90	19	RIFFLE	WA850S
DEADFALL CR.	31-Aug-94	2552.70	12	RIFFLE	WA856S
CAMP CR.	21-Sep-94	917.10	25	RIFFLE	WA848S
KIMTA CR.	26-Sep-94	510.80	27	RIFFLE	WA835S
THREE PRUNE CR.	27-Sep-94	961.40	24	RIFFLE	WA836S
TRB QUINAULT R.	19-Oct-94	1267.50	22	RIFFLE	WA840S
PYSHT R.	20-Oct-94	851.50	26	RIFFLE	WA861S
COOK CR.	12-Jul-95	5220.70	7	RIFFLE	WA011S
COAL CR.	01-Aug-95	5503.20	6	RIFFLE	WA007S
WEST TWIN CR.	02-Aug-95	1449.10	20	RIFFLE	WA009S
TRB QUINAULT R.	03-Aug-95	3218.50	11	RIFFLE	WA840S
NF CROOKED CR.	08-Aug-95	1677.40	18	RIFFLE	WA003S
TRB CLOQUALLUM	10-Aug-95	7001.70	5	RIFFLE	WA018S
PYSHT R.	17-Aug-95	1317.70	21	RIFFLE	WA861S
SF SKOKOMISH R.	22-Aug-95	4790.10	8	RIFFLE	WA028S
PINE CR.	24-Aug-95	1960.20	15	RIFFLE	WA029S
CLOQUALLUM CR.	05-Sep-95	1874.80	16	RIFFLE	WA019S
NF SALMON R.	26-Sep-95	2296.40	14	RIFFLE	WA089S
TRB QUINAULT R.	27-Sep-95	1716.90	17	RIFFLE	WA840S
PYSHT R.	28-Sep-95	2422.00	13	RIFFLE	WA861S

Table 4. Invertebrate density data of riffle habitats for 1994 and 1995 (Washington State Department of Ecology).

Results

There was no significant difference between the Pool categories in streams with and without Harlequins (p<.10) so the null hypothesis is accepted. In the Riffle category there was a highly significant difference between streams with and without Harlequins (p<.0001) enabling the rejection of the null hypothesis.

Discussion

These results support the value of food resources in riffle habitats to the distribution of Harlequin ducks. This has implications for maintaining water quality, the integrity of a health riparian habitat and the collective integrity of all the forces surrounding and supporting this ecosystem. Harlequin ducks are apparently closely linked to their food source and dependent on its availability to reside in a particular area.

Initially it was this author's intent to correlate hatching times to invertebrate densities on the streams where the Harlequin duck is documented. The invertebrate data and the hatching data are not extensive enough.

The factors influencing and limiting this analysis are the availability of data points (four dates among two years for the streams with Harlequins) and the time of year, which is later than the peak of the breeding season. Hatching occurs in Washington in mid-May through July and it takes approximately 42 days to fledge which puts the broods on the stream until September. The dates for the invertebrate density data are August and very early October which are still relevant, but limited. The availability of food in August and October is not necessarily an indicator of food availability earlier in the season. However, stream habitat providing resources for the later larval emergences is likely to provide similar high quality resources earlier in the season.

The usefulness of this exercise is the implications for more relevant ways of collecting data in the future specifically for the purpose of understanding the relationship between invertebrate densities, water quality and the support of wildlife.

CHAPTER SIX: LAND MANAGEMENT, HUMAN ACTIVITIES AND RECOMMENDATIONS

Introduction

The habitat setting provided for the Harlequin duck by the richness of the Olympic Peninsula is beyond comparison. It has a unique history both geologically and as a result of the influence of European settlers and the U.S. government. The following is a very short treatment of the history and current issues surrounding the plight of the Harlequin duck on the Olympic Peninsula, located in the Northwestern corner of the State of Washington. Two governmental domains are highlighted, the Olympic National Park and the Olympic National Forest, because of their domination of the landscape and influence on the management habitat of the Olympic Peninsula.

THE OLYMPIC PENINSULA

Olympic National Park

Olympic National Park is located on the Olympic Peninsula of Washington State (Figure 3). The park boundaries encompass 908,720 acres of contiguous area (Lyons and Satterfield 1992), and contain the isolated coastal Olympic mountain range (McNulty 1996). The geological formation of this area is impressive. The Olympic and the North Cascade Ranges originated through the tectonic mechanisms of plate subduction, folding and faulting that created sharp peaks. This process began an estimated hundred million years ago and was completed by several glacial stades culminating in the Vashon glacier. This glacier finished the formation of Puget Sound and essentially isolated the Olympic Peninsula about two million years ago (Kruckeberg 1991).

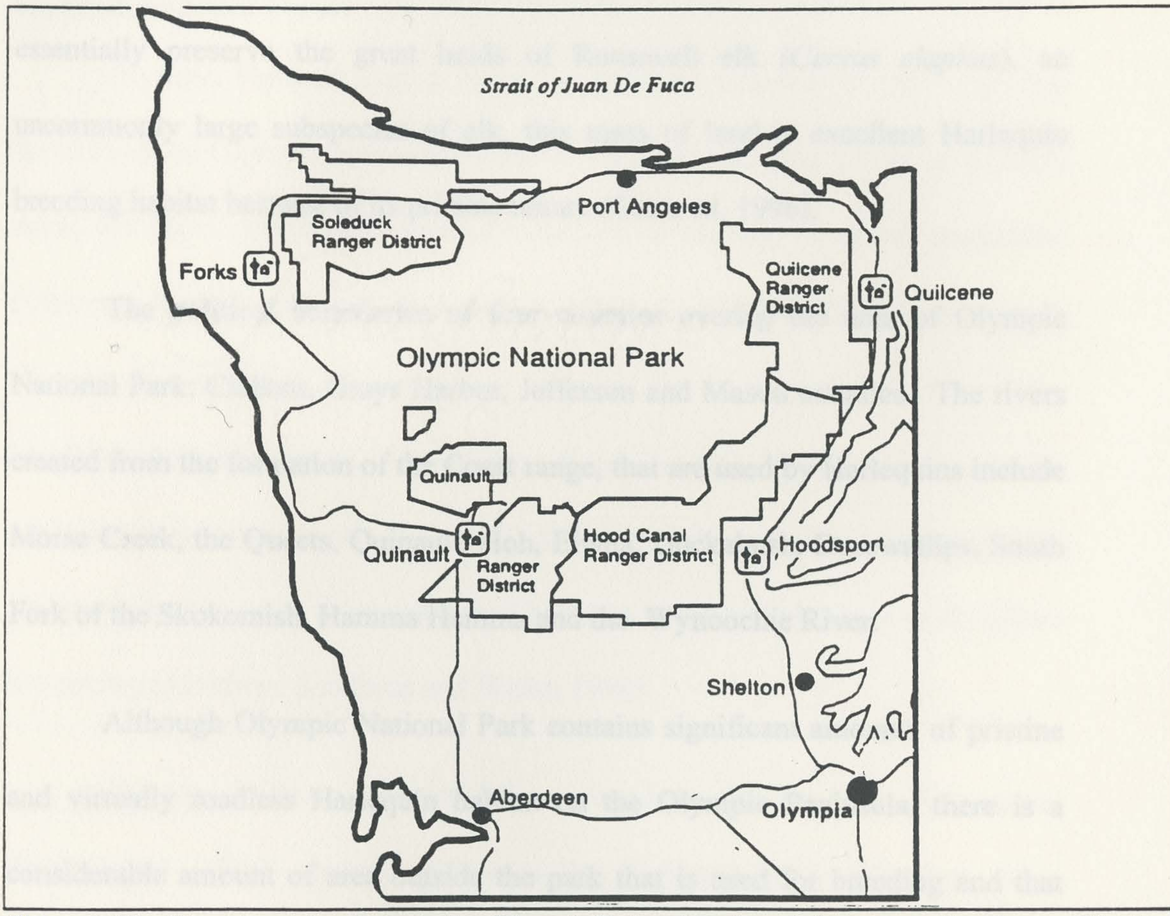

Figure 3. The Olympic peninsula including Olympic National Park and the surrounding Ranger Districts (U.S.Forest Service).

The ecology of the Olympic landscape is characterized primarily by large amounts of precipitation (up to 200 in/yr.). There are approximately 600 miles of hiking trails available to the public seasonally. The highest peak is nearly 8000' rising directly from sea level. The park provides a unique and superlative opportunity to explore an area like no other in the world. Originally set aside to essentially preserve the great herds of Roosevelt elk (*Cervus elaphus*), an uncommonly large subspecies of elk, this mass of land is excellent Harlequin breeding habitat because of its pristine nature (Gates ed. 1996).

The political boundaries of four counties overlap the area of Olympic National Park: Clallam, Grays Harbor, Jefferson and Mason counties. The rivers created from the formation of the Coast range, that are used by Harlequins include Morse Creek, the Queets, Quinault, Hoh, Elwha, Duckabush, Dosewallips, South Fork of the Skokomish, Hamma Hamma and the Wynoochie River.

Although Olympic National Park contains significant amounts of pristine and virtually roadless Harlequin habitat on the Olympic Peninsula, there is a considerable amount of area outside the park that is used for breeding and that provides sufficient habitat. The ownership and stewardship of these other lands is under the authority of such diverse groups and interests such as the National Forest Service, the State of Washington Department of Natural Resources, Simpson's Shelton Cooperative Sustained Yield Unit, several Indian Reservations including the Quinault, Makah, the Skokomish, and private citizens (Olympic

National Forest Plan 1993). The management of these lands is based on varied and wholly different philosophies of land use. These differences are counterproductive and affect the uniform management of ecosystems for the health and diversity of plant and animals species.

Olympic National Forest

Olympic National Forest began as a Forest Reserve in 1897 and was formally titled Olympic National Forest in 1905. It occupies a total of 632,000 acres, 447,000 of which are classified tentatively as suitable for timber production (Olympic National Forest Plan 1993). Olympic National Forest surrounds Olympic National Park (Figure 3). It is prized for its silvicultural productivity and its economic potential. The history of the Olympic National Forest and its evolution to its present state is a conglomeration of the maturing of management philosophies that range from rapacious harvests to the initial stages of dominant use zoning (Alverson, Kuhlman and Waller 1994).

The use of Olympic National Forest has been dominated by silvicultural development, which generally threatens the Harlequin duck. However, other values managed for in this vast expanse of habitat can benefit the Harlequin. Some of these values include scenery, recreation, water quality and wildlife habitat.

The potential designation of Wild and Scenic Rivers provided for under the Wild and Scenic Rivers Act of 1968 for the Dosewallips, Duckabush, main stem and West Fork of the Humptulips, Hoh, Bogaciel, and Soleduck rivers should not be overlooked in supporting the interests of the Harlequin duck. Additional rivers described in the "Nationwide Rivers Inventory" under the Wild and Scenic Rivers Act are the three main branches of the Calawah, the Dungeness, Gray Wolf, Big Quilcene, Hamma Hamma, Skokomish, South Fork Skokomish, Wynoochee, East Fork Humptulips, Quinault, and Elwha rivers. The majority of these rivers support Harlequins and when listed will also benefit this species (Olympic National Forest Plan 1993).

The rest of this chapter will address the historic and current human activities on the Olympic Peninsula, the influence of riparian ecology, some general and specific information about Harlequin duck production along the riparian ecosystem some management issues and concerns and some final recommendations from the study that went into creating this paper.

HUMAN ACTIVITIES

Historic Events

Riparian systems and climate are essential to the Harlequin on the Olympic Peninsula. The impact of humans with their political boundaries and land use practices has reduced the availability of good breeding habitat. The tension between the Forest Service and the Park Service began as a theoretical argument of conservation (U.S. Forest Service) versus preservation (U.S. Park Service) over one hundred years ago when president Grover Cleveland was given the congressional go ahead to preserve forest lands. That tension has persisted to this day on the Olympic Peninsula as a political battleground of land use versus biological integrity (McNulty 1996).

Olympic National Park was created on June 29, 1938 by Franklin D. Roosevelt after a long struggle with the politically powerful timber industry and the Forest Service. It was set aside originally as Mount Olympus National Monument in 1909 by the power of Theodore Roosevelt. The timber industry's attempt to harvest the land as soon as possible before the momentum of protectionism became strong delayed the process of creating a National Park and allowed for the loss of a great deal of indigenous habitat that has not regenerated. The Olympic Peninsula is a sanctuary of temperate rain forest catchments. The most intact and pristine reaches of these catchments exist within the Olympic National Park. The furious competition between the Forest Service and the Park Service cannot be underestimated in the goal of promoting pristine habitat for the Harlequin. Each entity has its own goals and ideals, which create competition for natural, undisturbed habitat (McNulty 1996).

Current Threats and Management

The Harlequin duck is a game species and an ecological indicator species. It is made clear in the writings of Ruggiero et al. (1988) that the preferences of a species should be weighted equally or better with those components of habitats considered requirements. Preferences give a species the ability to persist through time because preferences provide flexibility in the selection of habitat.

The complexity of defining components, requirements and preferences of habitat is understated in much of the literature about the Harlequin duck. Understanding the various details of habitat requirements and preferences provides for the more accurate use of dependency as a conceptual framework rather than a strict checklist of habitat features that become standard in every management plan. For the Harlequin this means that the variations in each ecotype should be taken into consideration when designing management goals and guidelines rather than making broad assumptions about the species based on research and observations made of separate populations.

Human caused threats are the primary focus of habitat management, proposed solutions and current policy. These threats span the entire habitat of the Harlequin. On the coast, they face the devastation of oil spill contamination, over hunting, encroachment of shoreline development and other commercial activities. On the streams, they are confronted with the destruction of riparian areas and degradation of watershed stability and stream flow regime by mining, roads or timber harvest. Disruption in the form of inundation or elimination of breeding habitat by river impoundment and diversion, and disturbance by recreational river users and hikers in breeding areas are activities of concern in the effort to manage and protect the Harlequin duck (Cassirer 1991; Clarkson 1992; Genter 1993; Goudie 1996; Hunt 1993; Wallen 1987; Status 1993).

that human activity can have when they alter to the active river channel. For example, some commercial and recreational activity increases overland flow in the riparian ecosystem which can potentially have a negative effect on the Harlequin ducks during their breeding season.

Both state and federal regulations impact the management of the Harlequin duck. However, the most critical and influential implementation of these regulations is at the local level. The rivers used by the Harlequins empty into the four counties and the management of wildlife is determined by political boundaries and regions, thus the determination of important habitat features must be collectively determined and policy agreed upon by people with differing values and priorities.

Management interests are diverse and sometimes the influences of resource management are not evident. The most clear examples of this are from a state and federal regulation that impact the habitat of the Harlequin. At the state level the mapping and designation of the Harlequin under Priority Habitat and Species gives land owners and managers the opportunity to take the Harlequin duck into consideration under the Washington Growth Management Act (1990) (WDFW-PHS 1991). At the Federal level designation of the Harlequin as a Sensitive Species by the Forest Service in some regions and the regard provided for by the National Environmental Policy Act in the development of habitat gives some leverage to the protection of this species.

The conservation of the Harlequin duck under the Endangered Species Act was a missed opportunity. The designation of this species as Category 2 was an important sanctioned device that is no longer an option for managing the conservation of the Harlequin as long as its status is inactive.

Recommendations

The impetus of this paper was to make a critical assessment of the nature of information and management practices regarding the Harlequin duck on the Olympic Peninsula and to come up with some original conclusions about this species. The largest issue in the specific goals of this paper was the lack of data for analysis. The stream habitat is invaluable to the Harlequin duck. The conclusiveness of the data and analysis in this paper is weak but relevant.

<u>Investigation Recommendations</u>

Stream flow data should be collected daily during the breeding season from areas on the streams where this species is actually seen. Analyzing the stream flow data from the U.S. Geological Survey is interesting and provides broad information at the level of the watershed. However to get more resolution for the understanding of the influences of stream flow on breeding activity, gauging of stream fluctuation on specific breeding streams is critical.

Brood survey data should be collected more often to provide increased data points within years and across areas. Additional time spent observing and surveying females with broods will provide increased information and opportunities to see more birds. This kind of data collection will provide information on habitat utilization, timing and activity in the breeding habitat and give a better indication of production on the breeding grounds. Arrival on the breeding grounds, nesting and breeding observations are also important for the evaluation of the Harlequin duck as an indicator species, a Priority Habitat Species, a Species of Special Concern and a potential candidate for listing under the Endangered Species Act.

Further data on food utilization are necessary. This involves developing a non-lethal means of collecting gizzard contents plus doing benthic invertebrate sampling in the exact locations where the birds are feeding. This data will provide critical and fundamental biological knowledge currently unavailable for this population of Harlequin ducks.

These goals could be achieved with well placed gauging devices on the stream, more technical support in surveying the streams that are used by Harlequins during their breeding season and increased awareness by habitat professionals and the outdoor public.

Refinements of benthic invertebrate data collection would include specific locations, less variable kick samples (at this point the variation is from one to eleven kicks per sample; G. Merritt, pers. comm. 5/9/97), and a compositional evaluation of species in order to infer what might be eaten by Harlequins on the streams. Furthermore, invertebrate collection dates should be more frequent during reproduction events such as arrival on the stream, nesting and hatching.

Management Recommendations

Known Harlequin breeding areas should be considered sensitive to modification and impact during the times when the species is actually present. Reducing impacts on the stream environment through education and limited degradations from recreation and resource extraction are priority concerns in the management and conservation of the Harlequin duck on the Olympic Peninsula.

Although this species is vulnerable in its maritime habitat because of oilspills and other types of hapless environmental degradation, the nature of its existence in the freshwater environment and the management of this species along the stream should not be diminished by the imbalance in current practices. There is not so much a lack of study or information in some cases but a lack of support from the administration to accomplish the necessary analysis by the Washington State Department of Fish and Wildlife.

Consistent with other findings and studies the state of Washington must be conscious of the impacts of resource extraction from areas adjacent to the breeding streams, overuse and alteration of the structure and hydrological processes of relevant riparian areas.

LITERATURE CITED

Aldrich, J.W. 1973. Disparate sex ratios in waterfowl. D.S. Farner, ed. Breeding biology of birds, pp. 482-489. National Academy of Sciences, Washington D.C.

Alstad, D.N. 1982. Current speed and filtration rate link caddisfly phylogeny and distributional patterns on a stream gradient. Science 216:533-534.

Alverson, W.S., W. Kuhlman and D.M. Waller. 1994. Wild Forests: Conservation Biology and Public Policy. Island Press. Washington D.C.

Baldassarre, G.A. and E.G. Bolen. 1994. Waterfowl Ecology and Management. John Wiley and Sons, Inc. New York. 609 pp.

Bellrose, F.C. 1980. Ducks, Geese And Swans Of North America. Stackpole Books. Harrisburg, Pennsylvania.

Bengtson, S.-A. 1966. Field studies on harlequin duck in Iceland. Wildfowl Trust 17th Annual Report, pp. 79-94.

Bengtson, S.-A. 1972. Breeding Ecology of the Harlequin duck *Histrionicus histrionicus*. Iceland. Ornis Scand. 3:1-19.

Bengtson, S.-A. and S. Ulfstrand. 1971. Food resources and breeding frequency of the Harlequin duck *Histrionicus histrionicus* in Iceland. Oikos 22:235-239. Copenhagen.

Beschta, R.L. and W.S. Platts. 1986. Morphological features of small streams: significance and function. Water Resources Bulletin 22(3):369-379. American Water Resources Association.

Breault, A.M. and J.-P. L. Savard. 1991. Status report on the distribution and ecology of the harlequin ducks in British Columbia. Tech. Rept. Series No. 110, Canadian Wildl. Serv., Pacific and Yukon Region, British Columbia. 108 pp.

Cassirer, E.F. and C.R. Groves. 1991. Harlequin duck ecology in Idaho: 1987-1990. Dept. of Fish and Game, Non-game Endangered Wildl. Prog. 93 pp.

Cassirer, E.F., G. Schirato, F. Sharpe, C.R. Groves, and R. N. Anderson. 1993. Cavity nesting by harlequin ducks in the Pacific Northwest. Wilson Bull. 105:691-694.

Chadwick, D.H. 1993. The Harlequin duck: Bird of white waters. National Geographic Magazine 184(5):116-132.

Clark, J.D., J.E. Dunn and K.G. Smith. 1993. A multivariate model of female black bear habitat use for a Geographical Information System (GIS). J. Wildl. Manage. 57(3):519-526.

Clark, T.W., R.P. Reading and A.L. Clarke. 1994. Endangered Species Recovery. Island Press, Washington D.C. Ch. 10, pp. 227-250.

Diamond, S. And P. Finnegan. 1993. Harlequin Duck Ecology on Montana's Rocky Mountain Front. U.S.D.A. Forest Service, Lewis and Clark National Forest, Rocky Mountain District, Choteau, Montana 59422. 73 pp.

Donovan, M.L., D.L. Rabe and C.E. Olson, Jr. 1987. Use of Geographic Information Systems to develop habitat suitability models. Wildl. Soc.

Bull. 15:574-579.

Dzimbal, K.A. 1982. Ecology of Harlequin ducks in Prince William Sound, Alaska during summer. M.S. Thesis. Oregon State University, Corvallis, Oregon. 89 pp.

Fleishner, T.L. 1983. Natural history of Harlequin ducks wintering in northern Puget Sound. M.S. Thesis Western Washington University, Bellingham. 48 pp.

Friederici, P. 1996. White-water diver. Birder's World. 10(3):54-57.

Gaines, W.L. and R.E. Fitzner. 1987. Winter Diet of the Harlequin duck at Sequim Bay, Puget Sound, Washington. Northwest Science. 61(4):213-215.

Gaines, William L. 1993. Habitat use by Harlequin ducks on the Wenatchee National Forest: A preliminary report, November 1993. U.S. Forest Service, Leavenworth Ranger District.

Gardarsson, Arnthor and Arni Einarrson. 1994. Responses of breeding duck populations to changes in food supply. Hydrobiologia 279/280: 15-27. J.J. Kerekes (ed.) Aquatic birds in the Trophic Web of Lakes. Kluwer Academic Publishers. Belgium.

Gates, J. (ed.) 1996. Mount Rainier and Olympic National Parks Magazine. American Park Network. Fifth edition pp. 40-87.

Genter, Dave. 1993. Whitewater wonder. Montana Outdoors. 24(4):2-7.

Gollop, J.B. and J.F. Marshall. 1954. A guide to aging duck broods in the field.

Mississippi Flyway Council Technical Section Report. 9 pp.

Goudie, R. Ian. 1996. Demography of Harlequin ducks in coastal British Columbia, 1994-95 Field Report. 31 pages.

Goudie, R.I. and C.D. Ankney. 1986. Body size, activity budgets and diets of sea ducks wintering in Newfoundland. Ecology 67(6):1475-1482.

Gregory, S.V., F.J. Swanson, W.A. McKee and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41(8):540-551.

Hewlett and Nutter. 1969. An Outline Of Forest Hydrology. Surface water, streamflow and the hydrograph (Ch. 7). 137 p.

Hirsch, K.V. 1980. Winter ecology of sea ducks in the inland marine waters of Washington. M.S. Thesis, Univ. of Washington, Seattle. 92 pp.

Hochbaum, H.A. 1946. Recovery Potentials in North American waterfowl. Trans. North Am. Wildl. Conf. 11:403-416.

Hunt, W.A. 1993. Jasper National Park Harlequin duck research project, 1992 pilot projects - interim results. Jasper Warden Service Biological Report Series, No. 1, Heritage Resource Conservation, Parks Canada, Box 10, Jasper, Alberta, T0E 1E0. 67 pp.

Huston, M. 1979. A general hypothesis of species diversity. American Naturalist 113(1):81-101.

Inglis, I.R., John Lazarus and R. Torrance. 1989. The pre-nesting behavior and time budget of the Harlequin duck *Histrionicus histrionicus*. Wildfowl 40:55-73.

Jackson, Lawrence. 1990. Flying with Falcons: A helicopter search for endangered birds in Labrador. Canadian Geographic. August/September p.28-34.

Jarvis, Robert L. and Howard Bruner. 1996. Characterization of habitat used by breeding Harlequin ducks in Oregon. Department of Fisheries and Wildlife. 19 pages.

Johnsgard, P.A. 1960. Classification and relationships of the sea ducks. Condor 62:426-443.

Kruckeberg, A.R. 1991. The natural history of Puget Sound country. University of Washington Press. Seattle. 468 pp.

Kuchel, C.R. 1977. Some aspects of the behavior and ecology of Harlequin ducks breeding in Glacier National Park, Montana. M.S. Thesis, Univ. Mont., Missoula. 156 pp.

LaFave, L.D. 1955. Breeding record for Western Harlequin duck from Spokane, Washington. The Murrelet 36(2): 17.

Land and Resource Management Plan for the Olympic National Forest Pacific Northwest Region. 1990. United States Department of Agriculture. 70 pp.

Lyons, D.J.B. and A. Satterfield. 1992. Washington Handbook. Moon Publications Inc. Chico, Calif. 433 pp.

McNulty, T. 1996. Olympic National Park: a natural history guide. Boston, Mass. Houghton Mifflin Co. 272 pp.

Merritt, G. Washington State Department of Ecology. Personal communication, May 9, 1997.

Merritt, R.W. and K.W. Cummins. 1978. An Introduction To The Aquatic Insects Of North America. Kendall/Hunt Publishing Co. Iowa.

Owen, M. and J.M. Black. 1990. Waterfowl Ecology. Chapman and Hall. New York. 194 pp.

Perfido, N. 1997. Unpublished data. University of Washington, Seattle.

Plotnikoff, R.W. 1992. Timber/Fish/Wildlife Ecoregion Bioassessment Pilot Project. Washington State Department of Ecology. Watershed Assessments Section. 57 pp. Appendices A-J.

Proceedings of a Harlequin duck symposium, held at Hornsby Island, Straight of Georgia, B.C., March 13-15, 1994. Harlequin Duck Working Group, Canadian Branch. 22 pages.

Proceedings, Harlequin Duck Symposium, April 23-24, 1992, Moscow, ID. Idaho Department of Fish and Game. 43 pp.

Rodrick, E. and R. Milner., Eds. 1991. Management Recommendations for Washington's Priority Habitats and Species. Washington Department of Wildlife.

Ruggiero, L.F., R.S Holthausen, B.G. Marcot, K.B. Aubry, J.W. Thomas and E.C. Meslow. 1988. Ecological Dependency: The concept and its implications for research and management. Trans. 53rd N.A. Wildl. And Nat. Res. Conf. 115-126.

Salomonsen, F. 1968. The moult migration. Wildfowl 19:5-24.

Schirato, G. 1994. Experimental radio transmitter attachment for Harlequin ducks. Washington State Department of Fish and Wildlife unpublished report. 4 pp.

Schirato, G. 1994. Status of Harlequin ducks in Washington. Washington State Department of Fish and Wildlife unpublished report. 4 pp.

Soule, M.E. 1987. Viable Populations for Conservation. Cambridge University Press, Cambridge, England. 183 p.

Stanford, J.A. and J.V. Ward. 1992. Management of aquatic resources in large catchments: recognizing interaction between ecosystem connectivity and environmental disturbance, pp. 91-124. In: Naiman, R.J. (ed.). Watershed Management. Springer-Verlag, New York. 542 pp.

Status of Harlequin ducks (*Histrionicus histrionicus*) in North America. 1993. Report of the Harlequin Duck Working Group.

Status Report on the Harlequin duck in Washington State in 1994. U.S. Fish and Wildlife Service. 27 pages.

Turbak, G. 1997. Enigma on the wing: The bizarre life of the Harlequin duck. National Wildlife 35(1): 34-39.

United States. National Park Service. 1974. Wilderness recommendation: Olympic National Park, Washington. Washington, U.S. Government Printing Office.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47(4): 893-901.

Vermeer, K. 1983 Diet of the Harlequin duck in the Strait of Georgia, British Columbia. The Murrelet 64(2): 54-57.

Wallen, R.L. 1987. Habitat utilization by Harlequin ducks in Grand Teton National Park. M.S. Thesis. Montana State University, Bozeman. 67 pp.

Wick, W.Q. and R.G. Jeffrey. 1966. Population estimates and hunter harvest of diving ducks in Northeastern Puget Sound, Washington. The Murrelet 47(2): 41-54.