ISLAND COUNTY STREAM/LAKE BUFFER

Best Available Science Update Paper

Prepared for:

Island County

November 2008

ESA Adolfson

This Page Intentionally Left Blank

CONTENTS

LIST OF TABLES

This Page Intentionally Left Blank

1.0 INTRODUCTION

The Washington State Growth Management Act (GMA, RCW 36.70A.172) requires that cities and counties review, and if necessary revise, their Critical Areas Ordinance (CAO) development regulations at least once every seven years. The GMA requires that the CAO be updated regularly using best available science. Best available science requires an assessment of peer-reviewed scientific research and synthesis by a qualified scientific expert. Island County adopted their current Island County Code (ICC) addressing the protection of Fish and Wildlife Habitat Conservation Areas in 2004 after a review of best available science.

The purpose of this paper is to update the best available science protection standards for streams and lakes. Providing an analysis and synthesis of recent scientific studies that relate to the effectiveness of different buffer types and widths for protecting stream and lake resources in Island County, this paper addresses the following questions:

- What stream and lake resources are present in Island County?
- What is the current best available science for protecting these resources, in particular with regards to buffers?
- What are the specific threats and pressures facing Island County streams and lakes?
- What is Island County currently doing to protect these resources?
- What types of buffer protection and management or other regulations could further protect Island County streams and lakes?

1.1 Stream, Lake and Buffer Definitions

Streams and lakes are important in the water cycle as they collect surface water from precipitation, ground water and surface water runoff, and they recharge groundwater or convey freshwater into oceans, depending upon geologic and weather conditions. In stream systems surface water flows through channels that have a defined bed and bank. Lakes are depressional features that store surface water for relatively long periods of time before it either evaporates, flows through an outlet, or recharges groundwater. Lakes and streams have a zone of influence where water interacts with land in a transitional area called a riparian area or zone.

Riparian areas are the zones where aquatic and terrestrial ecosystems interact. Riparian vegetation provides habitat for many species of wildlife, as well as other functions such as shade, bank stability, sediment/nutrient filtering, and organic nutrient input.

Riparian buffers are a regulatory rather than a biologically defined term, intended to protect streams, lakes, and other critical areas from development impacts. Riparian buffer areas usually extend beyond the riparian zone of influence into adjacent upland vegetation communities. In accordance with ICC 17.02.050.C.3, buffers are required to protect stream/riparian functions.

Streams and lakes and their associated riparian zones and buffers provide a variety of functions including, but not limited to, flood water storage, erosion control, water quality improvement, microclimate control, large woody debris input, and habitat.

Streams and lakes are protected as critical areas, defined as Fish and Wildlife Habitat Conservation Areas, in Island County. This broad grouping of areas is defined in Island County Code (ICC 17.02.030) as follows:

> **Fish and Wildlife Habitat Conservation Area**: *Land management for maintaining species in suitable habitats within their natural geographic distribution so that isolated subpopulations are not created.*

Stream and lake habitats are a subset of this broader critical area category, being defined in ICC 17.02.030 as follows:

> **Streams:** *Those areas where naturally occurring surface waters produce a defined channel, bed, bank or side, and where there is clear evidence of the passage of water such as bedrock channels, gravel beds, sand and silt beds and defined channel swales. The channel or bed need not contain water year-round. This definition is not intended to include irrigation or drainage ditches or swales, canals, storm or surface water run-off devices or other artificial watercourses unless they are used by salmonids or to convey streams naturally occurring prior to construction of such watercourses.*

> **Lakes:** *A lake twenty (20) acres or greater in size which is subject to the provisions of the Shoreline Management Act (Goss Lake, Lone Lake, Crockett Lake, Deer Lake, Kristoferson Lake, Cranberry Lake), and three (3) unnamed lakes located in Section 24, Township 29N, Range 2E (26 acres); Section 6, Township 31N, Range 1E (25 acres); and, Section 18, Township 33N, Range 2E (50 acres).*

Standard protective buffer widths for streams depend upon the regulatory classification of the stream (ICC 17.02.050.C.3). Lakes, as defined by ICC, only include those that are large enough to also be considered "Shorelines of the State." Lakes of this size are protected by the Shoreline Master Program that requires special provisions for any activities within 200-feet of the lake shoreline. Riparian buffers are not defined in ICC 17.02 (December 2004), but buffers are defined in relation to wetlands in the updated ICC 17.02B NEW Critical Areas Ordinance (July 2007) as follows:

> **Buffer:** *The area adjacent to the outer boundary of a Critical Area, measured in feet that protects the Critical Area from Alterations caused by a Development Proposal. Buffers for Wetlands will be established based on Land Use Intensity, the sensitivity of a Wetland to adverse impacts to Wetland Functions and Wetland Type. Wetland Buffers are presumed to be well vegetated with undisturbed vegetation.*

1.2 General Characteristics of Island County Streams, Lakes, and Buffers

General information about the physical and biological characteristics of Island County streams and lakes was gathered from Island County inventories, mapping, and monitoring and management plans, and best available science papers. A wetland inventory and best available science review wetlands and buffers were recently completed for Island County (Adamus et al., 2006b and Adamus, 2007). These papers provide background on the physical environment and wildlife species of Island County, and describe the importance of wetland buffers in Island County. Island County GIS mapping resources (Island County, 2008) provide information on stream and lake systems and related vegetation cover. The recent surface water monitoring report (Adamus, 2006a) provides information on water quality concerns in Island County.

Fish habitat and use is described in the *WRIA 6 (Whidbey and Camano Islands) Multi-Species Salmon Recovery Plan* (SRP, 2005), *Habitat Limiting Factors: Water Resource Inventory Area (WRIA) 6 Island County* (WDOE, 2005), and *Island County Creek Restoration Planning 2003-2004* (Washington Trout, 2006).

1.2.1 Physical Features

Island County includes Whidbey Island, Camano Island, and several smaller islands in and near Deception Pass. These islands are located in north Puget Sound with Fidalgo Island of Skagit County to the north, Skagit and Snohomish Counties to the east, Snohomish and Kitsap Counties to the south, and Jefferson County and the Strait of Juan de Fuca to the west.

The topography is rolling, ranging in elevation from 100 to 300 feet, rising to 500 feet in a few places. The steepest slopes, many up to 15 to 25 percent, are on the south portion of Whidbey Island (Ness and Richins, 1958). Most land rises up to ridges positioned centrally, with slopes and drainages generally oriented in east-west directions, except in close proximity to the north-south oriented bays and harbors.

Soils are glaciated, consisting of stratified sand, gravel, and some clay. Glacial upland soils, gravelly and sandy drift and till, cover approximately 75 percent of Island County. Most soils in Island County drain well. Gravelly sandy loam and loamy sand soil types are common. Gravelly and sandy outwash soils are found on terraces. Soils in depressions tend to contain more clay and organic material and are poorly drained (Ness and Richins, 1958).

Of the total 126 drainage sub-basins in Island County, 86 are located on Whidbey Island and 40 are located on Camano Island. The relatively steep and rolling topography, lack of snow pack, and porous soils on the islands result in many seasonal, shallow-channeled streams (WDOE, 2005). Island County is different than most other Western Washington counties in that there are no rivers and most of the streams are small coastal streams, only a few of which have perennial flow. Maxwelton Creek, with a mainstem approximately four miles long, is located in the largest watershed of Island County, covering 11.6 square miles (Figure 1). Most drainage basins contain multiple drainage pathways to Puget Sound, while a few form true watersheds where all surface water flows into Puget Sound via a single stream (SRP, 2005). Numerous other basins deliver no surface water via streams to Puget Sound.

Smaller lakes are generally positioned in upper basin areas, while larger lakes are located closer to the coast, often associated with coastal lagoons.

1.2.2 Biological Resources

Island County was covered with dense forest before European settlement in the late 1800s and early 1900s, except for some smaller areas of prairie grassland (Ness and Richins, 1958). Most prairie areas were converted to agriculture, but relatively large, continuous areas of native conifer and deciduous forests remain in some areas of Island County. Old growth and mature forest stands are located in Deception Pass State Park on the north end of Whidbey Island (WDFW, 2008). Wetlands are found throughout Island County and include unique habitats such as bogs, estuaries, and coastal lagoons.

Island County is located adjacent to some the most productive river estuaries in Puget Sound, including the Skagit, Stillaguamish, and Snohomish. These highly productive areas along with the numerous bays and smaller estuaries located along Island County's marine shorelines make Island County an important foraging and sheltering area for many fish and wildlife species. Eight species of salmonids use nearshore habitats of Island County during juvenile life stages (SRP, 2005). Numerous bald eagle nesting territories and waterfowl concentration areas occur in shoreline areas and in coastal lagoons and lakes (WDFW, 2008). The quality and quantity of freshwater entering the productive marine nearshore areas of Island County contributes to the health of Puget Sound and the numerous bays and estuaries of Island County.

1.2.2.1 Streams

Though marine nearshore areas of Island County are highly productive for fish, most of the small, coastal streams of Island County do not provide surface water flows required to support salmonids and other fish species (SRP, 2005). Fish use has been documented in only six of the 126 total drainage basins (SRP, 2005). Island County has approximately 220 miles of stream, of these approximately 40 miles are located in these six basins (Figure 1). Three basins, Kristoferson, Maxwelton, and Glendale, contain habitat for anadromous and resident fish, and three basins, North Bluff, Dugualla, and Chapman, provide habitat for resident fish including coastal cutthroat trout, three-spine stickleback and sculpin (SRP, 2005; Washington Trout, 2006)(Figure 1). Kristoferson Creek, on the northeast coast of Camano Island, provides habitat for juvenile Chinook, coho, and chum salmon, though the stream sometimes goes dry in summer. Maxwelton Creek, on the southwest coast of Whidbey Island, is the only stream that is known to have coho spawning and rearing habitat (SRP, 2005; Washington Trout, 2006). Glendale Creek, on the southeast coast of Whidbey Island, supports coho and chum juvenile salmon rearing. Lakes are also found in the Maxwelton, Kristoferson, and Dugualla basins.

The smaller basins with greater topographic relief tend to have more forested cover than those with valley land that is more suitable for building and agriculture (Table 1-1; Figure 2). Smaller, steeper basins such as Glendale, Chapman and North Bluff tend to have a much higher percent of stream miles surrounded by forest and overall forest cover in their basin. However, native riparian vegetation is narrow or absent along many streams in lower elevation valleys, such as in the Maxwelton and Dugualla basins.

Table 1-1. Summary of Forested Stream Miles and Basins

Basins	Fish Use	Total Stream Miles	Forested Miles	Percent Forested Miles	Total Basin Area (Acres)	Forested Basin Area (Acres)	Percent Forested Basin Area
Maxwelton	Anadromous	17.5	6.93	40%	7153	4580	64%
Kristoferson	Anadromous	3.74	0.55	15%	2410	1346	56%
Glendale	Anadromous	2.81	2.02	72%	1399	998	71%
Dugualla	Resident	11.9	0.56	5%	7004	1728	25%
Chapman	Resident	2.69	1.76	65%	1291	878	68%
North Bluff	Resident	2.2	1.85	84%	543	482	89%
Fish Stream - Subtotals		**40.84**	**13.67**	**33%**	**19800**	**10012**	**51%**
Draining to Bays, Harbors, and Coves	No	96	36.62	38%	45065	20995	47%
Draining to other coastline	No	83.9	59.2	71%	27283	17065	63%
Totals		**261.58**	**109**	**42%**	**111948**	**58084**	**52%**

Forested stream miles were calculated using the National Land Cover 2001 dataset (http://www.epa.gov/mrlc/nlcd-2001.html, and http://www.epa.gov/mrlc/classification.html). Areas classified as Deciduous Forest, Evergreen Forest, Mixed Forest, and Scrub/Shrub were considered forested for this analysis. Forested stream miles are all lengths of stream that intersect these land classification types.

1.2.2.2 Lakes

A wide variety of lake habitats exist in Island County (Table 1-2). Many are associated with unique habitats such as bogs and coastal lagoons, and many are connected with large tracts of forest. The development density is low around most of the lakes. Like Island County's streams, these lakes are important in that they provide a fresh water source and habitat for many wildlife species and most have direct connections with the rich nearshore marine habitats of Island County. Large concentrations of wintering waterfowl and migrating shorebirds are documented using Crockett Lake, Hancock Lake, and Deer Lagoon (WDFW, 2008). Dugualla Pond, Kristoferson Lake, and Miller Lake have documented fish use as they are connected to resident fish-bearing streams. Miller Lake is located in the upper basin and is connected to Maxwelton Creek, the only stream known to have coho spawning in Island County. Kristoferson Lake is also known for wood duck nesting (WDFW, 2008).

Many of the lakes drain to nearshore habitats that are priorities for protecting and restorating juvenile salmon and forage fish according to the salmon recovery plan (Table 1-2; SRP, 2005). The nearshore protection and restoration priorities for different shoreline segments were identified as part of the Northwest Straits Nearshore Habitat Evaluation (Anchor Environmental, 2002 as cited in SRP, 2005). The assessment for juvenile salmon was based on five habitat functions: high energy refuge, physiological refuge, predator refuge, migration corridor, and food production; an assessment of adjacent vegetation; regional landscape context (distance to natal rivers); and a shoreline modification score. The assessment for forage fish was based on historical forage fish records, physical habitat, adjacent vegetation, landscape context, and a shoreline modification score.

Table 1-2. Characteristics of Lakes in Island County

Lake	Lake/Basin Area** (Acres)	Surrounding Habitats	Basin Description	Stream Basin Fish use/ Protection Priorities (SRP, 2005)	Nearshore Habitat Protection Priorities (SRP, 2005)	Nearshore Habitat Restoration Priorities (SRP, 2005)
Bos Lake* / Coastal lagoon Also called Swan Lake	Approx. 75/ 3793	Wetlands and agriculture	Drains to coastal lagoon before entering Strait of Juan de Fuca	Salmonid habitat/ moderate	Juvenile salmon – moderate	Juvenile salmon – moderate Forage fish – moderate
Cranberry Lake	192/ 1401	Large forest patches, bog, coastal lagoon	Drains to coastal lagoon and beach habitat	None	Juvenile salmon – moderate Forage fish – high	None
Crockett Lake* / Coastal lagoon	385/ 5143	Mix of wetland habitats, agriculture, developed areas, and forest	Drains to Admiralty Bay	Salmonid habitat/ moderate	Juvenile salmon – high Forage fish – moderate	Juvenile salmon – high
Deer Lake	79/ 974	Medium-sized forest patches and low density development	Coastal stream draining to beach	Salmonid habitat/ moderate	Juvenile salmon – high Forage fish – moderate	Juvenile salmon – high Forage fish – moderate
Dugualla Pond	51/ 6970	Agriculture	Dugualla Basin, drains to Dugualla Bay tidelands	Resident fish observed/ moderate	Juvenile salmon – high Forage fish – moderate	Juvenile salmon – high Forage fish – moderate
Goss Lake	52/ 1780	Medium-sized forest patches bordered by a ring road with low density development	Basin drains to Holmes Harbor Lake appears to be within a smaller, closed sub-basin	None	Juvenile salmon – high Forage fish – very high	Juvenile salmon – high Forage fish – high
Hancock Lake	Coastal basin	Large forest patch and beach, associated with coastal lagoon	Drains to Admiralty Inlet, not mapped as a basin	None	Juvenile salmon – very high Forage fish – moderate	None
Hastie Lake* Surface water is present seasonally	Approx. 54/ 1670	Low density development, roads, forest patches of various sizes and agriculture	Drains to Penn Cove	None	Juvenile salmon – high Forage fish – moderate	Juvenile salmon – moderate Forage fish – very high

Lake	Lake/Basin Area** (Acres)	Surrounding Habitats	Basin Description	Stream Basin Fish use/ Protection Priorities (SRP, 2005)	Nearshore Habitat Protection Priorities (SRP, 2005)	Nearshore Habitat Restoration Priorities (SRP, 2005)
Honeymoon Lake	Approx. 5 /1319	Low density development and small forested patches bordered by ring road	Drains to Honeymoon Bay	Salmonid habitat / moderate	Juvenile salmon – very high Forage fish – very high and high	Juvenile salmon-moderate Forage fish – very high
Kristoferson Lake	7/ 2644	Agriculture and large patch forest	Kristoferson Basin, drains to Triangle Cove and coastal lagoon	Anadromous salmon observed/ high	Juvenile salmon – high Forage fish – high	Juvenile salmon – high Forage fish – high
Lone Lake	85/ 5748	Low density rural/agricultural development	Drains to Useless Bay and coastal lagoon	Salmonid habitat/ moderate	Juvenile salmon – high	Juvenile salmon – high
Miller Lake	6-acre bog/ 7025	Associated wetlands are bordered by large patches of forest	Maxwelton basin, drains to south end of Useless Bay	Anadromous salmon observed/ high	Juvenile salmon – very high and high Forage fish – high and moderate	Juvenile salmon – moderate Forage fish – high
Newman Lakes*	40 (approximate combination of smaller lakes)/ 5747	Associated with bogs and bordered by medium and large patch forest with some areas of clearing and roads nearby	Headwater lakes connected to streams that drain to Useless Bay	None	Juvenile salmon – high	Juvenile salmon – high
Oliver Lake	12 /1385	Large forest patch	Headwater lake, drains to Deer Lagoon and Useless Bay	None	Juvenile salmon – high	Juvenile salmon – high
Parego's Lake	18	Between beach and large forest patch	Coastal drainage area/not mapped as basin area	None	Juvenile salmon – moderate Forage fish – moderate	None
Silver Lake	14/ 895	Large forest patch	Drains to developed pocket estuary	None	Juvenile salmon – high Forage fish – high	Juvenile salmon – moderate Forage fish – high

*Habitats of Local Importance

**Lake sizes are from Washington Department of Ecology Lakes GIS data or were approximated from LIDAR using GIS tools, approximations are noted in table; basin sizes are from Island County GIS.

Stream and lake riparian buffers that have remained vegetated with native trees and shrubs or have been restored to this condition provide important water quality and habitat functions in Island County and the surrounding marine waters (Adamus, 2007). The pressures on the remaining forested buffer areas is highest where current development has already resulted in greater pollutant loads, habitat loss and degradation (Adamus 2006a; Adamus et al., 2006b). These areas require the greatest protection.

1.2.2.3 Special Status Species

Special status species that are most closely associated with stream and lake riparian habitats include western toad, coho and Chinook salmon, three species of bats, bald eagle, great blue heron, osprey, and purple martin (Table 1-3). Special status species include those with federal, state, or local protection status. The western toad is most dependent upon these habitats throughout Island County as this species breeds in open water and disperses over long distances into forested and shrub buffers. Coho and Chinook salmon are also dependent upon stream habitats with high quality buffers; however, their distribution in Island County is limited to one basin and three basins, respectively . The other species of bats and water-related birds (bald eagle, great blue heron, osprey, and purple martin) depend upon riparian habitats for the production of their prey and they roost and nest in adjacent buffer areas.

Two state sensitive plants are also found near lakes and streams, though only one has been recently recorded in Island County on Camano Island (WDNR, 2008). Several other special status species, including water birds like common loon and western grebe and other salmonids, are mostly associated with marine nearshore areas rather than directly with fresh water resources. A few other birds, such as pileated woodpecker, merlin, and Vaux's swift, forage in forested riparian areas, but these species are not common in Island County and they are found in a variety of upland habitats as well as in riparian areas.

This list of special status species has changed since the Fish and Wildlife Habitat Conservation Area section of ICC 17.02 was updated in December 2004. For example, since bald eagle populations are continuing to grow, the bald eagle is not longer listed as a threatened species, but is a federal species of concern and a state sensitive species.

Table 1-3. Special Status Species in Island County

Common Name	Scientific Name	Habitat Use in Island County	Special Status
MAMMALS			
Keen's myotis	*Myotis keenii*	Generally associated with riparian and open water areas, roosts in caves, beneath tree bark and in tree snags, commonly forages over open water and in forest openings	State Candidate
Long-eared myotis	*Myotis evotis*	Same habitat use as Keen’s myotis	Federal Species of Concern
Townsend's big-eared bat	*Corynorhinus townsendii*	Roosts exclusively in caves and other more open roosts, otherwise similar habitat use to other bats above.	Federal Species of Concern State Candidate
BIRDS			
Bald eagle	*Haliaeetus leucocephalus*	Solitary nests in tall trees, mainly in marine coastline areas of Island County, forages mainly in the marine nearshore and in lakes and wetlands, common resident of Island County	Federal Species of Concern State Sensitive
Great blue heron	*Ardea herodias*	Several nesting colonies located on Whidbey Island, forages mainly in the marine nearshore and in lakes and wetlands, common resident of Island County	State Monitor Local Importance
Osprey	*Pandion haliaetus*	Nests in shoreline areas, mainly marine shorelines in Island County, forages and nests on tall trees, snags, or other structures near open water (fresh or marine), uncommon in Island County	State Monitor Local Importance
Peregrine falcon	*Falco peregrinus*	Forages in a variety of habitats, mainly for birds and sometimes on small mammals, nests on cliffs and large buildings, some breeding evidence but uncommon in Island County	State Candidate
Purple martin	*Progne subis*	Closely associated with open water where they feed and breed, rare in Island County, breeding on Camano Island	State Candidate
Pileated woodpecker	*Dryocopus pileatus*	Generally associated with riparian areas, nests in tree cavities, uncommon in Island County	State Candidate Species of Local Importance
Vaux's swift	*Chaetura vauxi*	Forages in riparian and open water areas, rare spring and fall migrant	State Candidate
Merlin	*Falco columbarius*	Forages in riparian and open water areas, uncommon in Island County	State Candidate
Common loon	*Gavia immer*	Common during fall, winter, and spring in estuaries and marine waters	State Sensitive Local Importance
Western grebe	*Aechmophorus occidentalis*	Common during fall, winter, and spring in estuaries and marine waters	State Candidate
Clark’s grebe	*Aechmophorus clarkii*	Occasional visitor in fall, winter, and spring in estuaries and marine waters	State Monitor

Common Name	Scientific Name	Habitat Use in Island County	Special Status
Horned grebe	*Podiceps auritus*	Common during fall, winter, and spring in estuaries and marine waters	State Monitor
Trumpeter swan	*Cygnus buccinator*	Occasional migrant or winter visitor to the marine nearshore and open water areas such as lakes and coastal lagoons	Local Importance
REPTILES AND AMPHIBIANS			
Western toad	*Bufo boreas*	Breeds in ponds, lakes, and slow moving streams in Island County, closely associated with riparian and open water areas, disperses widely through forest and shrub thickets	Federal Species of Concern State Candidate
FISH			
Puget Sound Chinook salmon	*Oncorhynchus tshawytscha*	Marine nearshore and Kristoferson Creek used by juveniles for rearing, marine nearshore also used for migration	Federal Threatened State Candidate
Puget Sound coho salmon	*Oncorhynchus kisutch*	Spawning and rearing in Maxwelton Creek, juvenile rearing in Glendale and Kristoferson Creeks, rearing and migration in marine nearshore areas	Federal Species of Concern
Hood Canal summer chum	*Oncorhynchus keta*	Foraging habitat for larger juveniles and migration corridors for adults along marine shorelines of Camano and Whidbey Islands	Federal Threatened State Candidate
Coastal-Puget Sound bull trout	*Salvelinus confluentus*	Foraging habitat for larger juveniles and migration corridors for adults along marine shorelines of Camano and Whidbey Islands	Federal Threatened State Candidate
PLANTS			
Bulb-bearing water-hemlock	*Circuta bulbifera*	Known historically (before 1980) in Island County, grows along lake and marsh edges, in shallow water and in slow-moving streams	State Sensitive Local Importance
Black lily	*Fritillaria camschatcensis*	One current occurrence on Camano Island, grows near lakes and streams and other moist habitats	State Sensitive Local Importance

References: Smith et al., 1997; Adamus 2008 wildlife Table 2-5; Seattle Audubon Society, 2008; WDNR, 2008; SRP, 2005.

2.0 THREATS AND PRESSURES

Stream and lake ecosystems in Island County can be adversely affected by existing and future development. Residential and other site development requires site clearing and grading, resulting in habitat loss. The loss of native habitats adjacent to streams and lakes generally results in a loss of breeding sites, sheltering areas, and foraging opportunities for native wildlife species that are associated with these habitats in Island County. Loss of vegetation near streams and lakes also degrades the quality of these habitats. When sites are cleared and graded, soils are compacted, surface water runoff increases, and invasive plant species spread into newly disturbed areas.

Site development tends to increase impervious surfaces in drainage basins, potentially changing stream and lake hydrologic conditions. An increase in impervious surface causes higher peak flows in streams during precipitation events, which can cause stream bank erosion and sedimentation. Streams generally become more channelized, pool and riffle habitats are lost or degraded, and channels become are incised. In-stream and riparian habitat for a variety of aquatic organisms is lost or degraded. Lakes may also experience greater fluctuations or changes in water levels, resulting in habitat changes.

Site development may also cause pollutants to enter streams and lakes during or after construction, negatively affecting water quality. The potential for soil erosion is high during construction when it rains. Soil erosion can cause sedimentation in streams, resulting in loss or degradation of in-stream habitat for aquatic organisms. Sediments are a major transport mechanism for phosphorus, which can impairs streams and cause eutrophication of lakes. Other pollutants from developed sites may include petroleum products, nitrogen and other nutrients from fertilizers, pesticides, and toxic substances related to a particular development. These pollutants can be toxic to fish and wildlife species and they degrade water quality and habitat conditions in streams and lakes.

3.0 CURRENT REGULATIONS AND MANAGEMENT

Current land use regulations, monitoring and management by Island County guide the continued protection of streams, lakes and surrounding native habitats.

3.1 Regulations and Zoning

The County's CAO protects wetlands, streams, wetland and stream buffer areas, and species and habitats of local importance. Island County critical area and buffer protection regulations apply to all new developments and to most modifications of existing developments. Buffer regulations restrict land uses and protect existing soils and vegetation adjacent to streams and lakes to protect streams and lakes from development impacts. Standard buffer widths in ICC 17.02 range between 150 feet for lakes classified as "Shorelines of the State" to 25 feet for WDNR Type 5 streams that are not a tributary to a salmon-bearing stream or are not located in the Rural Zone.

Protection of species and habitats is generally handled on a case-by-case basis. Projects that do not meet standard requirements, such as the 75-foot buffer for Fish and Wildlife Habitat Conservation Areas require the preparation of a Biological Site Assessment by a qualified professional or a management plan in the case of bald eagles. Protected species that may inhabit stream and lake habitats include bald eagle, peregrine falcon, great blue heron, common loon, osprey, pileated woodpecker, and trumpeter swan. Nest sites of these species are protected, except for trumpeter swan as they do not nest in Island County.

The CAO protects nine areas identified as habitats of local importance that include over 6,000 acres of habitat for migratory birds and waterfowl. Four lakes and their associated wetlands are regulated as Habitats of Local Importance by ICC 17.02.110.C. These include Bos Lake, Crockett Lake, Hastie Lake, and Newman Lakes.

Island County also requires the use of Best Management Practices (BMPs) to protect the water quality and other functions of lakes and streams during site development. All new developments are required to use BMPs for temporary erosion and sedimentation control. These usually include preserving existing vegetation, marking clearing limits, using silt fencing or other means of trapping sediments, and routing stormwater through dense strips of vegetation to remove sediments. Site developments that create more than 5,000 square feet of impervious surface or are located within critical areas including streams, stream buffers, or areas within 200 feet of a lake shoreline are also required to control stormwater flow rate and water quality. Mitigation must be provided for developments that change the stormwater flow rate and/or water quality.

The County has also adopted Agricultural BMPs for improving water quality of streams, wetlands and nearshore areas within or near agricultural areas. And vegetation along County roads is controlled by mowing only; no spraying of herbicides is allowed.

Zoning directs the density of development in Island County. As part of the growth management planning process 93% of Island County was down-zoned to low density rural zone (1 dwelling per 5 acres). This down zoning keeps the overall percent of impervious surfaces low in Island County and vegetation cover relatively high, benefitting critical areas such as streams and lakes.

3.2 Science and Monitoring

Water Resources Inventory Area 6 (Whidbey & Camano Islands) Multi-Species Salmon Recovery Plan was adopted by the Board of Island County Commissioners and Island County Water Resources Advisor Committee in May 2005. This plan describes priorities for protection and restoration of nearshore, stream, and basin areas for the recovery of multiple species of salmon, their prey, and habitat. Island County supports or participates in a variety of other science and monitoring efforts that protect stream and lake habitats including:

- An ongoing surface water monitoring program identifies exceedences of water quality thresholds and works to locate and address the source of these exceedences (Adamus, 2006a).

- A comprehensive survey of the County’s 958 known wetlands was conducted using spatial data maps from many sources, and new field data was collected in 2005 from a representative sampling of 103 of these wetlands, covering about one-third of the County’s total wetland area (Adamus et al., 2006b). This information has been used to update wetland regulations and management guidelines in ICC 17.02B.

- Washington Trout (2006) has performed comprehensive watershed assessments on Maxwelton Creek and Chapman Creek to identify restoration opportunities for improving stream conditions for salmonid habitat.

3.3 Planning and Education

Island County now offers the use of a Rural Stewardship Plan to residents as an alternative to conforming land use to standard wetland regulations. Rural Stewardship Plans offer a comprehensive approach to protecting wetlands on Island County because they consider all aspects of site planning and encourage the use of Low Impact Development (LID) for minimizing impacts to critical areas.

Island County provides publications to residents that describe best management practices and encourage the use of low impact development techniques to protect stream, wetland, and other watercourse buffers. A good example of this is the *Guide to Clean Water* published in September 2007.

4.0 BUFFER WIDTHS AND BEST AVAILABLE SCIENCE

This section discusses the functions provided by riparian buffers of varying widths as reported in recent literature. Buffer functions are relatively high in many areas of Island County because a variety of healthy native habitats are found along most streams and lakes. The quality of the buffers in Island County is likely related to the existing buffer regulations and management practices and the fact that and development densities are low.

Vegetated buffers have potential to improve the quality of surface water flowing through them. Maintaining water quality is a primary concern for Island County because the potable water supply for residents is from aquifers that are susceptible to contamination from surface water sources (Adamus, 2006a). Nearshore habitats, also susceptible to contamination entering from adjacent freshwater bodies, are critical for the marine food web that supports economically important salmonid fisheries and shellfish harvest (WDOE, 2005; WDNR, 2001).

Riparian buffers in Island County also provide habitat for a variety fish and wildlife species. Vegetated buffer areas in Island County vary in width from a few feet in developed and agricultural areas to 1,000 feet or more in forest management and protected areas. The numerous streams and lakes of Island County create a network of fish and wildlife habitat that connects terrestrial with freshwater and nearshore ecosystems

The primary functions of water quality improvement and habitat provided by Island County riparian buffers are described in the literature in terms of the pollutant type treated and habitat features provided. These subcategories are covered in this report as follows:

<u>Water Quality</u>

- Sediment removal
- Nutrient removal
- Bacteria removal

Fish and Wildlife Habitat

- Stream temperature and microclimate
- Large woody debris recruitment
- Fish spawning and rearing
- Stream invertebrate and amphibian breeding and rearing
- Mammal refugia and movement
- Bird habitat

4.1 Water Quality

Vegetated buffers are known to remove sediment, nitrogen, phosphorus, bacteria, and other pollutants in surface and ground water. Removal rates vary depending upon the pollutant type, landscape, and site conditions.

Many physical, chemical, and biological mechanisms operate to improve water quality in surface water flowing through buffers. Some of the most influential of these include water retention and infiltration, topography (low relief), plant uptake of nutrients, chemical transformation, and soil, vegetation, and hydrologic conditions (Abu-Zreig et al., 2004; Parkyn, 2004; Polyakov et al., 2005; Mayer et al., 2007). Dense buffer vegetation generally increases treatment of surface water quality (Hruby et al., 2004).

Island County has relatively good conditions for water quality treatment because steeper slopes that convey runoff at a more rapid rate are generally well vegetated while the more developed areas with greater potential pollutant loads are usually in areas with lower gradients. Most soils in Island County are course-grained and infiltrate well.

The ability of a buffer to treat runoff is also a function of the volume of water the buffer receives. Riparian buffers do not receive equal amounts of runoff because their contributing basins vary in area and slope. Large basins or basins that receive large amounts of runoff may require wider buffers. Therefore, a variable buffer width design may be appropriate for achieving the greatest efficiency in terms of treating this variable runoff (Polyakov et al., 2005). In this case, buffer widths would be greater where they receive higher amounts of runoff, especially where this runoff is known to contain pollutants.

Several studies conclude that vegetated buffers have a greater effect on stream water quality high in the watershed near stream headwaters compared to the lower watershed (Schultz et al., 2004; Polyakov et al., 2005; Mayer et al., 2005). Tributary streams higher in the watershed generally receive runoff from larger catchment areas than main stem, first order streams. Though this would mainly be a factor to consider in the larger basins of Island County where several tributary streams join a main stem stream rather than in the smaller, coastal stream systems.

Many studies examine the effectiveness of vegetated filter strips (VFSs) of varying widths for improving surface water quality. VFSs are bands of permanent vegetation adjacent to streams or drainage ditches designed to provide water quality treatment, usually in agricultural areas (Abu-

Zreig et al., 2004). VFSs are sometimes only composed of densely planted grasses. Or they may consist of different vegetation zones. One common design is a three-zone system with unmanaged forest nearest the stream, followed by a managed tree stand, with a dense grass strip on the outside adjacent to agricultural land (Schultz et al., 2004; Lowrance and Sheridan, 2005). Filter strips and multi-zoned buffers are widely used in agricultural and silvicultural settings to slow the movement of water, thereby allowing time for sediments, nutrients, or pollutants to drop out of suspension or to be absorbed.

VFSs work best when flow is shallow and dispersed evenly on slopes that are relatively flat. Water retention and infiltration also enhance the ability of VFSs to remove sediments, nutrients, and pollutants from surface water flows (Mankin et al., 2007).

4.1.1 Sediment Removal

Excess sediments in surface water can present problems to various aquatic organisms. Sedimentation can cause a decrease in plant photosynthesis and changes in plant communities, as well as smothering aquatic insect and amphibian eggs and salmon spawning redds (Adamus 2006b).

Watershed and site-specific factors that influence the ability of vegetated buffers to remove sediment from surface waters include, but are not limited to:

- buffer width,
- vegetation type (height and density),
- initial soil water content,
- topography,
- surface water flows (sheet or concentrated, low or high, fast or slow) and
- sediment characteristics (particle size, fall velocity, aggregate density) (Polyakov et al., 2005).

Of these factors, buffer width plays the most significant role under controlled experimental conditions (Abu-Zreig et al., 2004). Buffer widths reported to effectively remove sediments vary widely based on the other site attributes listed above, such as vegetation type, flow type and rate, and sediment particle size. For example, steep terrain is likely to concentrate flows, and high flows may inundate buffers leading to lower sediment removal efficiency (Polyakov et al., 2005).

Factors outside of the buffer, such as agriculture or urban development in the contributing basin, affect the sediment loads entering and exiting buffers. Lower sediment trapping efficiency values are recorded for buffers that receive greater sediment loads in other published studies (Abu-Zreig et al., 2004). This may be because the higher sediment loads may clog soil pores and overload the buffer's ability to trap sediments (Parkyn, 2004).

Much of the literature regarding sediment removal rates through vegetated buffers pertains to VFSs. VFSs that contain dense vegetation can be effective at removing a large percentage of sediment over a relatively short distance. Abu-Zreig et al. (2004) found that the sediment trapping efficiency of grass/legume filter strips 33 feet wide averaged 92% and did not improve further when the width was increased to 50 feet. Other controlled experiments have also confirmed that under sheet flow conditions, grass and grass-shrub buffer strips can provide relatively high levels of sediment removal (more than 90%) within 10 feet to 33 feet of the stream (Polyakov et al., 2005; Schultz et al., 2004; Mankin et al., 2007).

Grass-shrub buffers of 26 ft have been demonstrated to improve water quality through the removal of sediments, particularly if adequate infiltration is achieved (Mankin et al., 2007).

Lowrance et al. (in press) performed simulations that indicated sediment load reductions of 90% occurred with 55-foot wide buffers, with little increased sediment load reduction for larger buffers.

Recent literature reviews cite a range of effective buffer widths for sediment control. May (2000) identified a range of effective buffer widths for sediment removal and erosion control of 26 to 600 feet with a minimum recommendation of 98 feet for 80 percent sediment removal. Knutson and Naef (1997) reported a narrower range of effective buffer widths for sediment infiltration from 26 to 300 feet.

Employing appropriate BMPs in site design, such as infiltration basins or filter strips, can markedly reduce the risk of sediment transport into streams, thereby reducing the riparian buffer width required to effectively protect streams from impacts due to sedimentation (Parametrix et al., 2005).

4.1.2 Nutrient Removal

Nitrogen and phosphorus are primary surface water pollutants in agricultural areas and both nutrients, in particular nitrogen, are a concern in urban areas, especially in areas with septic drain fields. In excess, these nutrients can cause eutrophication (algae blooms) in lakes, streams, wetlands, and marine waters, and other environmental and health problems (Adamus, 2007; Mayer et al., 2007; Polyakov, 2004).

Phosphorus retention is closely associated with the retention of suspended sediments because sediment is the primary transport vector for phosphorus. Soil particles and organic matter in buffers adsorb phosphorus that is attached to sediments suspended in surface water flows (Polyakov, 2004). Therefore, many of the same factors that increase sediment removal in buffers also play a role in phosphorus removal.

Many studies have been conducted focusing on nitrogen, and to a lesser extent phosphorus, removal in agricultural settings. As with sediment removal, water retention and infiltration plays a major role in nitrogen and phosphorus removal (Mankin et al., 2007).

Three biological processes in buffers result in nitrogen retention: plant uptake, microbial immobilization, and bacterial denitrification (Mayer et al., 2007). Denitrification is most common in low oxygen areas such as wetland soils and the hyporheic zones of streams. These biological mechanisms depend upon site parameters such as the vegetation and microbial communities, soil properties, and site hydrology (Polyakov, 2004). More permanent nutrient retention capabilities are provided by the woody growth of trees and shrubs in buffers (Schultz et al., 2004). Subsurface processes generally provide more efficient removal than surface flow. Soil type, watershed hydrology, and subsurface biogeochemistry influence subsurface nitrogen removal (Mayer et al., 2007).

Vegetated buffers can be a source of nutrients as well as a nutrient sink. Plants in buffers cycle nutrients and some fix nitrogen in soil. Red alder, a nitrogen fixer, is common in riparian buffers in Island County and likely contributes nutrients to streams (Adamus, 2007). Nutrients can be released from the buffer through surface or groundwater when plants die or when nitrogen is released from soils. Soluble nitrogen levels measured in runoff exiting buffers have been higher than in runoff entering buffers in some studies (Polyakov, 2004). For Island County this may mean that even though vegetated buffers may retain nutrients and infiltrate well, buffers may actually be contributing more nutrients than they are removing.

Controlled experiments in agricultural areas demonstrate that relatively high levels of nutrient removal can occur in well designed vegetated buffer strips. Studies in the Bear Creek Watershed in Central Iowa concluded that a 23-foot wide native-grass buffer can reduce total nitrogen and phosphorus and nitrate and phosphate in surface runoff by at least 60%, while a combined 23-foot grass and 30-foot wide woody buffer reduced these nutrients by 80% (Schultz et al., 2004). In seven-year old grass-shrub buffers designed for filtering, Mankin et al. (2007) found that a buffer width of only 27 feet was effective at removing nitrogen and phosphorus. Removal rates for total nitrogen ranged from 79% to 98%, and removal rates for total phosphorus ranged from 77% to 98%.

A synthesis of a broad range of studies suggests that larger vegetative buffers are required to consistently remove nitrogen (Mayer et al., 2007). This meta-analysis of 89 individual riparian buffers from 45 published studies concluded that buffers more than 164 feet wide more consistently removed significant amounts of nitrogen than narrower buffers 0 to 82 feet wide. However, nitrogen removal in buffer areas of comparable widths varied widely among the studies, indicating that other factors affecting nitrogen removal are also in play.

Other recent literature reviews also cite a wide range of effective buffer widths that depend upon site conditions. Effective buffer widths ranged from 13 to 860 feet, with a minimum recommended width of 98 feet for 80% nutrient removal in May (2000). Knutson and Naef (1997) cite effective buffer widths ranging from 13 to 600 feet for pollutant removal.

Nitrate removal varied greatly at sites with different hydrogeologic characteristics on glacial till and outwash landscapes in southern Ontario, Canada (Vidon and Hill, 2004). Sites with more conductive sand and cobble sediments required buffers ranging from 82 feet to 577 feet to achieve more than 90% nitrate removal, whereas sites with loamy sand and sandy loam soils overlying a shallow confining layer at 3 to 6 feet achieved this removal rate within 50 feet.

In a controlled experiment in Georgia where geology limits aquifer recharge and most runoff remains in surface water or moves laterally in shallow saturated flow, three-zone managed vegetation buffers averaging 246 feet in width can reduce most nutrient loads from agricultural runoff before they reach a stream (Lowrance and Sheridan, 2005). The average slope of the field was 2.5 %. The three-zone buffer consisted of approximately 26 feet of dense grass (Zone 1), 50 to 198 feet of managed forest (slash pine and long leaf pine (Zone 2), and 50 feet of forest dominated by hardwoods (yellow poplar and swamp black gum)(Zone 3).

4.1.3 Bacteria Removal

Fecal coliforms (bacteria) from domestic animals and manure application have potential to contaminate surface and groundwater in Island County. Fecal coliforms may contaminate drinking water and reduce oxygen in water bodies. Buffer removal mechanisms may differ from those operating for sediments and nutrients. Fecal coliforms have densities similar to water and are similar in size to silt or coarse clay particles (Roodsari et al., 2005).

In agricultural areas, VFSs are used to reduce and minimize bacterial and chemical pollution inputs to streams through the filtering of bacteria and the physical-chemical alterations of pollutants. Studies of buffer effectiveness for fecal coliform removal frequently are concerned with animal/agricultural inputs to nearby waterways. In Maryland, Roodsari et al. (2005) found that grass (fescue and orchard grass) buffer strips measuring 10-13 ft in wide decreased surface runoff and transport of fecal coliform bacteria from land-applied manure under well-maintained conditions. Fecal coliform levels decreased to 1% of runoff in vegetated clay loam strips and to non-detectable levels in vegetated sand loam strips, even with slopes as high as 20%. Total runoff also decreased dramatically to 12% of total rainfall in vegetated clay loam and 2% of total rainfall in sandy loam, indicating that most runoff is retained and infiltrated in these strips (Roodsari et al., 2005).

4.2 BAS Limitations – Water Quality

Much variability has been demonstrated in the effectiveness of buffers to provide water quality treatment under different field and landscape conditions (Schultz et al., 2004; Mayer et al., 2005). This limits our ability to use case studies, which are the primary sources of information for buffer width comparisons (Polyakov et al., 2005), for making conclusions on appropriate riparian buffer widths for protecting water quality in Island County.

The conditions used in controlled experiments for testing water quality treatment in buffers, including sheet flow and relatively flat terrain, generally offer the greatest opportunities for testing hypothesis. In these controlled experiments, densely vegetated buffers ranging from 33 to 50 feet have been shown to provide a high level of sediment, nutrient, and bacteria removal. However, most of these studies are designed to test buffer effectiveness in agricultural areas rather than in mixed use residential areas that have different types of pollutant inputs, so their results may not be totally applicable to development conditions in Island County.

Recent literature focuses on removal of sediments, nitrogen, phosphorus, and fecal coliform bacteria by vegetated buffers before these potential contaminants reach surface waters. However, developed areas can also be a source of pesticides that are toxic to fish and wildlife species (Adamus et al., 2006b). How these additional contaminants are retained or transformed as they move through vegetated buffers likely differs from how other contaminants are treated in buffers. Additionally, pollutants may be transmitted into stream systems by alternate routes, such as tributary streams and stormwater outfalls that bypass vegetated buffers. This appeared to be the case in a rural watershed in New York where chlorine ions from road salt were higher in stream reaches with the largest vegetated buffers (Madden et al., 2007).

Island County has regulations that require the use of BMPs during construction for all site developments and permanent water quality treatment systems for larger site developments. In addition, Island County is currently conducting a water quality monitoring program to identify sources of pollutants and take actions to eliminate or manage these sources to achieve water quality improvement and natural resource protection (Adamus et al., 2006a). These actions by Island County indicate that wide, vegetated riparian buffers may not be necessary for maintaining a high standard of water quality in streams and lakes in Island County. Additionally, preliminary monitoring indicates few problems with surface water quality in Island County (Adamus et al., 2006a).

4.3 Fish and Wildlife Habitat

Riparian zones and their vegetated riparian buffers provide habitat to many aquatic organisms including fish, stream invertebrates, amphibians, and to some mammal, bird, and reptile species closely associated with the streams. Vegetated riparian buffers also provide wildlife species with partial or full terrestrial life stages habitat for feeding, cover, and breeding (Broadmeadow and Nisbet, 2004). And contiguous vegetated buffers may function as movement and dispersal corridors for these species (Stacier, 2005; Fellers and Kleeman, 2007).

Riparian zones are considered to be a critical habitat type for fish and wildlife management in western Washington as they usually contain a higher diversity of species than surrounding uplands (Johnson and O'Neil, 2001; Knutson and Naef, 1997). Riparian zones are different than buffers in that they are defined as the area of land that is influenced by a stream or other water body, buffers may extend beyond this zone of riparian influence.

Many species that inhabit Island County influence are closely associated with riparian areas and their buffers (Johnson and O'Neil, 2001) (Appendix A and 2-1). At least six fish species have been observed in Island County streams where fish are present (Washington Trout, 2006). Five mammals, 23 birds, seven amphibians, and one reptile in Island County are closely associated with and breed in stream riparian and open water areas (Table 2-1). Only two of these species are non-native and invasive (European starling and bullfrog). Another 14 mammals, 72 birds, and eight reptiles are generally associated and breed or feed in stream riparian areas. And another 32 birds, gulls, water birds, and shorebirds, are closely or generally associated with open water, though many of these are more common in marine habitats than in freshwater lakes or streams.

Table 4-1. Wildlife-Habitat Relationships in Island County

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
MAMMALS							
Deer mouse	*Peromyscus maniculatus*	CA/B		CA/B	CA/B	CA/B	
Muskrat	*Ondatra zibethica*	CA/B	CA/B		CA/B	GA/B	
River otter	*Lutra canadensis*	CA/B	CA/B		CA/B		
Raccoon	*Procyon lotor*	CA/B	GA/F	GA/B	CA/F	CA/B	
American beaver	*Castor canadensis*	CA/B	GA/R	GA/F	CA/B	P/F	
Townsend's chipmunk	*Tamias townsendii*	GA/B		CA/B			
Black bear	*Ursus americanus*	GA/B		GA/B	GA/F	GA/F	
Black-tailed deer	*Odocoileus hemionus col.*	GA/B		GA/B	GA/F	GA/B	
Coyote	*Canis latrans*	GA/B		GA/B	GA/F	GA/B	
Creeping vole	*Microtus oregoni*	GA/B		GA/B		GA/B	
Long-tailed weasel	*Mustela frenata*	GA/B		GA/B	GA/F	GA/B	
Townsend's vole	*Microtus townsedii*	GA/B		GA/B	CA/B	GA/B	
Red fox	*Vulpes vulpes*	GA/B		P/B		GA/B	
Big brown bat	*Eptesicus fuscus*	GA/B	GA/F	CA/B	GA/F	CA/B	
Keen's myotis	*Myotis keenii*	GA/B	GA/F	CA/B	GA/F		SC
Silver-haired bat	*Lasionycteris noctivagans*	GA/B	GA/F	CA/B	GA/F	P/F	
Long-eared myotis	*Myotis evotis*	GA/B	GA/F	GA/B	GA/F	P/B	FCo

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Townsend's big-eared bat	*Corynorhinus townsendii*	GA/F	CA/F	GA/B	GA/F	GA/B	FCo, SC
Hoary bat	*Lasiurus cinereus*	GA/F	GA/F	GA/F	GA/F	GA/F	
BIRDS							
California gull	*Larus californicus*		CA/B		GA/B	GA/F	
Clark's grebe	*Aechmophorus clarkii*		CA/B				SM
Eared grebe	*Podiceps nigricollis*		CA/B		CA/B		
Horned grebe	*Podiceps auritus*		CA/B		CA/B		SM
Northern rough-winged swallow	*Stelgidopteryx serripennis*		CA/B		CA/F	P/F	
Red-necked grebe	*Podiceps nigricollis*		CA/B		CA/B		
Ring-billed gull	*Larus delawarensis*		CA/B		GA/B	GA/B	
Western grebe	*Aechmophorus occidentalis*		CA/B		CA/B		SC
American coot	*Fulica americana*		CA/F		CA/B	GA/B	
Barrow's goldeneye	*Bucephala islandica*		CA/F		GA/F		
Canvasback	*Aythya valisineria*		CA/F				
Common goldeneye	*Bucephala clangula*		CA/F		P/F		
Dunlin	*Calidris alpina*		CA/F		CA/F	CA/F	
Eurasian wigeon	*Anas penelope*		CA/F		GA/F	GA/F	
Gadwall	*Anas strepera*		CA/F		CA/B	GA/B	
Glaucous gull	*Larus hyperboreus*		CA/F		GA/F		

VERTEBRATE SPECIES		**ASSOCIATION WITH HABITAT TYPES**					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Greater scaup	*Aythya marila*		CA/F				
Herring gull	*Larus argentatus*		CA/F		GA/F	GA/F	
Lesser scaup	*Aythya affinis*		CA/F		CA/B		
Northern pintail	*Anas acuta*		CA/F			GA/F	
Northern shoveler	*Anas elypeata*		CA/F		CA/B	GA/R	
Ruddy duck	*Oxyura jamaicensis*		CA/F				
Thayer's gull	*Larus thayeri*		CA/F		GA/F	GA/F	
Trumpeter swan	*Cygnus buccinator*		CA/F		CA/B	CA/F	
Western sandpiper	*Calidris mauri*		CA/F		CA/F	GA/F	
Common loon	*Gavia immer*		GA/B		CA/B		SS
Blue-winged teal	*Anas discors*		GA/F		CA/B	CA/B	
Bonaparte's gull	*Larus philadelphia*		GA/F			GA/F	
Cinnamon teal	*Anas cyanoptera*		GA/F		CA/B	CA/F	
Least sandpiper	*Calidris minutilla*		GA/F		CA/F	GA/F	
Long-billed dowitcher	*Limnodromus scolopaceus*		GA/F		CA/F	CA/F	
Short-billed dowitcher	*Limnodromus griseus*		GA/F			GA/F	
Warbling vireo	*Vireo gilvus*	CA/B				P/B	
Yellow warbler	*Dendroica petechia*	CA/B					
Band-tailed pigeon	*Columba fasicata*	CA/B		CA/B		GA/F	
Black-throated gray warbler	*Dendroica nigrescens*	CA/B		CA/B		P/B	

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Wilson's warbler	*Wilsonia pusilla*	CA/B		CA/B		P/B	
Barn swallow	*Hirundo rustica*	CA/B		GA/B	GA/F	CA/B	
Downy woodpecker	*Picoides pubescens*	CA/B		GA/B		GA/B	
European starling	*Sturmus vulgaris*	CA/B		GA/B	GA/F	CA/B	
Mourning dove	*Zenaida macroura*	CA/B		GA/B		CA/B	
Purple finch	*Carpodacus purpureus*	CA/B		GA/B		P/F	
Western screech-owl	*Otus kennicotti*	CA/B		GA/B	P/F	GA/B	
Willow flycatcher	*Empidonax trailli*	CA/B		GA/B		P/B	
Red-eyed vireo	*Vireo olivaceus*	CA/B		P/B			
Belted kingfisher	*Ceryle alcyon*	CA/B	CA/B				
Harlequin duck	*Histrionicus histrionicus*	CA/B	CA/F				
Hooded merganser	*Lophodytes cucullatus*	CA/B	CA/F	CA/R	GA/F		
Double-crested cormorant	*Phalacrocorax auritus*	P/B	CA/B		GA/R		
Canada goose	*Branta canadensis*	P/B	CA/F		CA/B	CA/F	
Cliff swallow	*Petrochelidon pyrrhonota*	CA/B	CA/F	GA/B	GA/F	GA/B	
Great blue heron	*Ardea herodias*	CA/B	CA/F	GA/R	CA/F	CA/F	SM
Wood duck	*Aix sponsa*	CA/B	CA/F	GA/R	P/F	GA/F	
Tree swallow	*Tachycineta bicolor*	CA/B	CA/F	P/B	CA/F	GA/B	
Spotted sandpiper	*Actitis macularia*	CA/B	GA/B		GA/B	GA/F	
Mallard	*Anas platyrhynchos*	CA/B	GA/F		CA/B	GA/B	

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Ring-necked duck	*Aythya collaris*	CA/B	GA/F		GA/B		
Brewer's blackbird	*Euphagus cyanocephalus*	GA/B			GA/B	CA/B	
Great horned owl	*Bubo virginianus*	GA/B			GA/F	GA/B	
Red-winged blackbird	*Agelaius phoenicens*	GA/B			CA/B	GA/B	
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	GA/B			CA/B	GA/B	
Savannah sparrow	*Passercullus sanwichensis*	GA/B			GA/B	CA/B	
Barred owl	*Strix varia*	GA/B		CA/B			
Golden-crowned kinglet	*Regulus satrapa*	GA/B		CA/B			
Northern pygmy owl	*Glaucidium gnoma*	GA/B		CA/B	P/F	P/F	
Olive-sided flycatcher	*Contopus borealis*	GA/B		CA/B			
Western tanager	*Piranga ludoviciana*	GA/B		CA/B			
Winter wren	*Troglodytes troglodytes*	GA/B		CA/B			
American crow	*Corvus brachyrhynchos*	GA/B		GA/B	P/F	CA/B	
American goldfinch	*Carduelis tristis*	GA/B		GA/B	GA/F	GA/B	
American kestrel	*Falco sparverius*	GA/B		GA/B	GA/F	GA/B	
American robin	*Turdus migratorius*	GA/B		GA/B	GA/F	GA/B	
Bewick's wren	*Thryomanes bewickii*	GA/B		GA/B	P/F	GA/B	
Black-capped chickadee	*Parus atricapilus*	GA/B		GA/B	P/F	P/B	
Black-headed grosbeak	*Pheucticus melanocephalus*	GA/B		GA/B		P/B	

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Brown creeper	*Certhia americana*	GA/B		GA/B		P/B	
Bushtit	*Psaltriparus minimus*	GA/B		GA/B		GA/B	
California quail	*Callipepla californica*	GA/B		GA/B		GA/B	
Cedar waxwing	*Bombycilla cedrorum*	GA/B		GA/B	P/F	P/B	
Chestnut-backed chickadee	*Parus rufescens*	GA/B		GA/B		P/F	
Common raven	*Corvus corax*	GA/B		FGA/B	GA/F	GA/B	
Common yellowthroat	*Geothlypis trichas*	GA/B		GA/B	CA/B	GA/B	
Cooper's hawk	*Accipiter cooperii*	GA/B		GA/B	GA/F	P/F	
Dark-eyed junco	*Junco hyemalis*	GA/B		GA/B		GA/B	
Evening grosbeak	*Coccothraustes vespertinus*	GA/B		GA/B			
Hairy woodpecker	*Picoides villosus*	GA/B		GA/B		GA/B	
House wren	*Troglodytes aedon*	GA/B		GA/B		P/B	
Hutton's vireo	*Vireo huttoni*	GA/B		GA/B		P/B	
MacGillivray's warbler	*Oporornis tolmiei*	GA/B		GA/B		P/B	
Northern flicker	*Colaptes cafer*	GA/B		GA/B		GA/B	
Orange-crowned warbler	*Vermivora celata*	GA/B		GA/B		P/B	
Pileated woodpecker	*Dryocopus pileatus*	GA/B		GA/B		P/F	SC
Pine siskin	*Carduelis pinus*	GA/B		GA/B	P/F	P/F	
Red-breasted nuthatch	*Sitta canadensis*	GA/B		GA/B		P/B	
Red-breasted sapsucker	*Sphyrapicus ruber*	GA/B		GA/B		P/B	

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Red-tailed hawk	*Buteo jamaicensis*	GA/B		GA/B	GA/F	CA/B	
Rufous hummingbird	*Selasphorus rufus*	GA/B		GA/B	P/F	GA/B	
Song sparrow	*Melospiza melodia*	GA/B		GA/B	GA/B	GA/B	
Spotted towhee	*Pipilo erythrophthalmus*	GA/B		GA/B		GA/B	
Steller's jay	*Cyanocitta stelleri*	GA/B		GA/B		P/B	
Swainson's thrush	*Catharus ustulatus*	GA/B		GA/B		P/B	
Townsend's warbler	*Dendroica townsendii*	GA/B		GA/B		P/F	
Turkey vulture	*Cathartes aura*	GA/B		GA/B	GA/F	GA/B	
Western wood pewee	*Contopus sordidulus*	GA/B		GA/B		GA/B	
White-crowned sparrow	*Zonotrichia leucophrys*	GA/B		GA/B	GA/F	GA/B	
Yellow-rumped warbler	*Dendroica coronata*	GA/B		GA/B	P/F	GA/F	
Ring-necked pheasant	*Phasianus colchicus*	GA/B		GA/F	GA/F	CA/B	
Brown-headed cowbird	*Molothrus ater*	GA/B		GA/R	GA/B	CA/B	
Barn owl	*Tyto alba*	GA/B	CA/F			CA/B	
Bufflehead	*Bucephala albeola*	GA/B	CA/F		CA/F		
Common merganser	*Mergus merganser*	GA/B	CA/F	CA/R			
Purple martin	*Progne subis*	GA/B	CA/F	GA/B	GA/F	P/B	SC
Vaux's swift	*Chaetura vauxi*	GA/B	CA/F	GA/B	GA/F	P/F	SC
Bald eagle	*Haliaeetus leucocephalus*	GA/B	CA/F	GA/R	GA/F	GA/F	FCo, SS
Osprey	*Pandion haliaetus*	GA/B	CA/F	GA/R		P/R	SM

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Pied-billed grebe	*Podilymbus podiceps*	GA/B	GA/B		CA/B		
Killdeer	*Charadrius vociferous*	GA/B	GA/B	P/B	GA/B	CA/B	
Merlin	*Falco columbarius*	GA/B	GA/F	GA/B	P/F	P/F	SC
Violet-green swallow	*Tachycineta thalassina*	GA/B	GA/F	GA/B	GA/F	GA/B	
Northern goshawk	*Accipiter gentilis*	GA/F		GA/B	GA/F		
Fox sparrow	*Passerella iliaca*	GA/F		GA/F		P/F	
Golden-crowned sparrow	*Zonotrichia atricapilla*	GA/F		GA/F	GA/F	GA/F	
Ruby-crowned kinglet	*Regulus calendula*	GA/F		GA/F	P/F	GA/F	
American wigeon	*Anas americana*	GA/F	GA/F		CA/B	CA/B	
Green-winged teal	*Anas crecca*	GA/F	GA/F		CA/B	GA/B	
Peregrine falcon	*Falco peregrinus*	GA/F	GA/F	GA/B	GA/F	P/F	SS
Bohemian waxwing	*Bombycilla garrulus*	GA/F		GA/F		GA/F	
Hermit thrush	*Catharus guttatus*	GA/B		GA/B		GA/F	
Mountain bluebird	*Sialia currucoides*	GA/B		GA/B		GA/B	
Townsend's solitaire	*Myadestes townsendi*	GA/F		GA/B		P/F	
REPTILES AND AMPHIBIANS							
Common garter snake	*Thamnophis sirtalis*	CA/B		GA/B	CA/B	GA/B	
Northern red-legged frog	*Rana aurora aurora*	CA/B	CA/B	CA/F	CA/B	GA/B	
Long-toed salamander	*A. macrodactylum*	CA/B	CA/B	GA/B	CA/B	GA/B	
Pacific treefrog	*Pseudacris (Hyla) regilla*	CA/B	CA/B	GA/B	CA/B	GA/B	

VERTEBRATE SPECIES		ASSOCIATION WITH HABITAT TYPES					
Common Name	**Scientific Name**	**Riparian/ Wetland - Forest and Shrub**	**Open Water – Lakes, Rivers, Streams**	**Upland Forest**	**Herbaceous Wetlands**	**Agriculture, Pastures, and Mixed Environs**	**Status**
CA – Closely Associated – A species is widely known to depend on a habitat for part of all of its life history requirements. GA – Generally Associated – A species exhibits a high degree of adaptability and may be supported by a number of habitats. P – Present – A species demonstrates occasional use of a habitat., B – Breeds and feeds, F – Feeds only, R – Reproduces only, O – Other, such as roosting, resting, hibernacula, or cover FCo – Federal species of concern, SS – State sensitive, SC – State candidate, SM – State monitor							
Bull frog	*Rana catesbeiana*	CA/B	CA/B	GA/F	CA/B	GA/F	Non-native
Northwestern salamander	*Ambystoma gracile*	CA/B	CA/B	GA/F	CA/B	P/F	
Rough-skinned newt	*Taricha granulosa*	CA/B	CA/B	GA/F	CA/B	GA/F	
Western toad	*Bufo boreas*	CA/B	CA/B	GA/F	CA/B	P/F	FCo, SC
Western terrestrial garter snake	*T. elegans*	GA/B			GA/F	GA/B	
Ensatina	*Ensatina eschscholtzii*	GA/B		CA/B		P/B	
Northern alligator lizard	*Elgaria coeruleus*	GA/B		GA/B			
Northwestern garter snake	*T. ordinoides*	GA/B		GA/B		GA/B	
Rubber boa	*Charina bottae*	GA/B		GA/B		GA/B	
Painted turtle	*Chrysemys picta*	GA/B	CA/F		CA/F	P/B	Non-native
Red-eared slider turtle	*Trachemys scripta*	GA/B	CA/F		CA/F	GA/R	Non-native
Snapping turtle	*Chelydra serpentina*	GA/B	CA/F		CA/F	GA/R	Non-native

Adapted from the CD Matrix provided in Johnson, D.H. and T.A. O'Neil. 2001. *Wildlife-Habitat Relationships in Oregon and Washington*. Oregon State University Press. Corvallis, Oregon.
Definitions:

Six stream basins in Island County provide habitat to salmonid species. Productive salmonid habitat is necessarily complex owing to the myriad requirements of different life stages. Salmonids require cold clean waters, silt-free substrates, natural flow conditions, and structurally complex habitat suitable for spawning, rearing, and migration. The aquatic habitat features important for supporting salmonid populations include riparian condition, LWD recruitment, fish passage, floodplain connectivity, channel migration, bank stability, pools, off-channel habitat, substrate/fines, water quality, and hydrology. Many of the aquatic habitat features listed as important for salmon are also important for other aquatic associated species such as invertebrates and amphibians.

Riparian vegetation interacts with natural erosional and depositional processes of streams as channels migrate across valley bottoms to form in-stream habitat. Channel migration also promotes floodplain connectivity and recruitment of LWD, which can be a primary factor influencing channel form by creating pools, riffles and off-channel habitats that are essential to support all life stages of anadromous salmonids as well as other aquatic species (May, 2000).

Historically, natural riparian corridors in the Pacific Northwest consisted of nearly continuous forest and the importance of riparian continuity is widely recognized (May et al., 1997; Naiman and Bilby, 1998; Wenger, 1999). Riparian corridor continuity is particularly important in smaller headwater streams because smaller streams generally make up most of the stream length within a watershed, and the influence of riparian vegetation on some stream habitat functions is greater for small streams (Binford and Bucheneau, 1993; Wenger, 1999; Beschta et al., 1987). The condition of riparian areas upstream of fish-bearing waters, including the marine waters surrounding Island County, helps determine water quality, the magnitude and timing of flows, temperature, sediments, nutrients, and prey production in downstream waters. Along lake shorelines, riparian vegetation is also a key element of ecological function and has a significant influence on the habitat value of the riparian zone, and in adjacent aquatic and terrestrial areas (Zelo and Shipman, 2000).

The following discussion is a review of major riparian habitat functions and the level of functionality afforded by riparian buffers of varying widths as reported in the literature. Tables 2-2, 2-3, and 2-4 summarize the conclusions and recommendations for riparian buffer widths in frequently cited literature reviews of riparian buffer functions. These tables are not intended to be prescriptive, but do serve to illustrate the wide range of effective buffer widths reported in the literature, and also provide recommendations based on providing a reasonable level of habitat functionality under most conditions. However, a single prescription is not necessarily appropriate or warranted for all situations. Buffer recommendations and functionality is frequently expressed in terms of site-potential tree height (SPTH), which is the height of mature trees that a given site can be expected to support.

Table 4-2. Stream Riparian Functions and Appropriate Widths Identified by May (2000)

Function	Range of Effective Buffer Widths	Minimum Recommended Width	Notes On Function
Large Woody Debris	10 to 100 m (33 to 328 ft)	80 m (262 ft)	1 SPTH based on long-term natural levels
Water Temperature	11 to 43 m (36 to 141 ft)	30 m (98 ft)	Based on adequate shade
Microclimate	45 to 200 m (148 to 656 ft)	100 m (328 ft)	Optimum long-term support

Table 4-3. Stream Riparian Functions and Appropriate Widths Identified by Knutson and Naef (1997)

Function	Range of Effective Buffer Widths (ft)
Large Woody Debris	100 to 200
Water Temperature	35 to 151
Microclimate	200 to 525

Table 4-4. Stream Riparian Functions and Appropriate Widths Identified from FEMAT (1993)

Function	Number of SPTH	Equivalent (ft)[1]
Large Woody Debris	1.0	200
Shade	0.75	150
Bank Stabilization	0.5	100
Organic Litter	0.5	100
Microclimate	up to 3	up to 600

How wide a buffer needs to be to provide effective habitat is also highly dependent on the wildlife species of interest (Table 2-5). For many forest birds and deer, riparian buffers should be at least 200 feet in width (Knutson and Naef 1997). To maintain the species number of neotropical migrant birds, Keller et al. (1993) and Hodges and Krementz (1996) recommended buffers of at least 328 feet (as cited in Knutson and Naef 1997).

[1] Note that this is based on a 200-ft SPTH (or that expected on a Class I site), and that equivalent functionality may be achieved by narrower buffers on sites having a narrower SPTH.

Table 4-5. Recommended Riparian Buffer Widths to Provide Effective Wildlife Habitat (Parametrix et al., 2005).

Wildlife Taxa	Buffer Width (ft)[1]
Invertebrates	100
Reptiles and amphibians	100 to 312
Forest dwelling birds	200
Neotropical migratory birds	328
Bald eagle	164 to 656
Great blue heron	328 to 984
Small mammals	39 to 305
Large mammals	200 to 328

4.3.1 Stream Temperature and Microclimate

Salmonids and other aquatic organisms are sensitive to high water temperatures in summer in Pacific Northwest streams. Vegetation in buffers and throughout the watershed helps to regulate stream temperatures and keep water cool in summer. Under undisturbed conditions, stream temperatures are maintained because the surface and groundwater that support flows are thermally protected by riparian vegetation and soils. As vegetation is removed from the watershed and from buffers, thermal protection is decreased and the ratio of surface-to-groundwater in a stream increases resulting in increased stream temperatures (Parametrix et al., 2005)

Riparian buffer's role in stream temperature moderation has been demonstrated in the literature, but buffer width effectiveness depends on site-specific factors such as the structure and composition of vegetation and stream width (Johnson and O'Neil, 2001). In a study conducted by Gomi et al. (2006) in coastal British Columbia, a 98-foot-wide riparian buffer was effective at minimizing forest harvest stream warming in headwater streams with widths ranging from 1.6 feet to 13 feet and channel gradients from 2 to 11%. Narrower channels that were re-vegetated after harvest showed less warming and recovered more rapidly. In addition, the north-south orientation of the streams in this study provided shading during the middle portion of the day (Gomi et al., 2005).

Sridhar et al. (2004) developed a predictive model for stream temperatures on the east and west slopes of the Cascades during "worst case" low flow – high summer temperature conditions. This model, confirmed by field data, showed that forested buffers more than 98 feet in width did not significantly decrease stream temperatures. In addition, other vegetation measures that may relate to land management, including leaf area index (ratio of leaf area per surface area) and average tree height, had more impact on maximum stream temperatures than buffer width (Sridhar et al., 2004).

Air temperature also influences the microclimate that sustains wildlife communities in riparian buffers and is affected by the structure, composition, and extent of riparian vegetation (Johnson and O'Neil, 2001). In a New Zealand study documenting the influence of forested riparian buffers on air temperature, Meleason and Quinn (2004) found that a 16-foot buffer provided a median reduction in maximum daily air temperatures of 3.2 °C, and a 98-foot buffer provided a reduction of 3.4 °C. Their results also indicated that forested riparian buffers of 16 feet can substantially moderate air temperatures compared to a harvested environment. This study may have application in Island County because the climate and vegetation are comparable, a pine plantation in a maritime temperate climate. This demonstrates that even restoring and/or protecting a riparian buffer as narrow as 16 feet can have substantial benefits for aquatic insects, amphibians and other animals that rely on the cooler, moister environment of riparian areas for thermoregulation.

4.3.2 Large Woody Debris Recruitment

Large woody debris plays a significant role in the creation of stream habitat complexity, flow moderation, cover and refuge habitat, and sediment storage and movement within the aquatic environment (Broadmeadow and Nisbet, 2004). The direct input of large woody debris to a stream channel from the riparian zone can trap sediments and smaller woody debris traveling downstream, thereby increasing habitat complexity and quality (Naiman et al., 2005). The removal of buffer vegetation reduces the recruitment of large woody debris to the stream and the habitat complexity of the aquatic and riparian environment. Development that changes stream channel movement potential, such as stream channelization or other stream bank modifications, also changes large woody debris recruitment.

Recommended buffer widths for providing LWD recruitment relate to the potential height of mature trees. The presence of mature trees and composition of the forest communities within tree length distance of the stream channel are more important metrics than measured buffer widths. On average, most large woody debris is from trees growing within 150 feet of the stream. Mature conifer trees in this buffer zone provide the best long term source of large woody debris as conifer wood breaks generally down more slowly than deciduous wood in the U.S. Pacific Northwest (Knutson and Naef, 1997).

4.3.3 Fish Spawning and Rearing

Fish resources are important in six stream systems in Island County (SRP, 2005). Riparian buffers provide habitat and conditions that are essential to fish survival and to the recovery of salmon stocks (Knutson and Naef, 1997). Riparian buffer functions critical to fish biology include water quality treatment, water temperature moderation, large woody debris recruitment, and habitat for foraging, rearing, and breeding. Buffer width recommendations for different stream functions that are important for salmonids are summarized from the literature in Tables 2-1, 2-2, and 2-3. May (2000) recommends a minimum buffer width of 100 feet overall, though some functional effectiveness may be lost in terms of microclimate and LWD recruitment. For full effectiveness buffers more than 600 feet wide are recommended for some functions. In many forested areas, buffers this wide are present in Island County. However, protecting buffers this wide may not be realistic where current land uses have already disturbed many buffer areas.

Landscape factors throughout a stream reach beyond riparian buffers also play a role in maintaining physical stream habitat for fish. As was found in agricultural areas in the Lower

Fraser Valley, factors such as plant community composition, structure, and level of disturbance both near the stream and throughout the landscape play a critical role in providing suitable habitat for native fish species (Elliott, 2003). In developing areas, stream morphology has been shown to change and stream ecosystems decline when impervious surfaces in stream basins exceed 10 percent (May et al., 1997). Changes in stream morphology caused by increased runoff from impervious surfaces can result in bank erosion that covers fish spawning areas with sediment and stream channelization that eliminates pools important for fish rearing.

In Island County the low residential density is likely important in maintaining stream morphology and preventing erosion and other impacts to streams. Regulations that influence how sites are developed (minimizing impervious surfaces, etc.) may be as important for protecting streams as buffer width. In addition to buffer width, the quality of vegetated buffers in Island County is also important in maintaining stream functions.

4.3.4 Stream Invertebrate and Amphibian Breeding, Rearing, and Dispersal

Stream invertebrates and amphibians are important in the food web and they affect nutrient cycling. Invertebrates are an important food source for fish and amphibians. In high densities, amphibian tadpoles control algae growth that has potential to lead to eutrophication (Johnson and O'Neil, 2001). All of the amphibian species that are found in Island County are closely associated with and breed in riparian and open water habitats. The six native species can breed in seasonal or permanent ponds, but non-native bullfrogs require permanent water for breeding.

Amphibians are in decline globally. They are more affected by changes in water quality than other species due to their close association and dependence upon water. In our region, the western toad, a state candidate and federal species of concern found in Island County, is in decline, with populations disappearing at known sites within short periods of time.

Invertebrate and amphibian species dependent on the aquatic environment for a portion of their life cycle can be affected by the extent and quality of riparian buffers bordering a stream. However, effective buffer widths required for maintaining a diversity of aquatic-associated invertebrates and amphibians varies considerably between studies (Parkyn, 2004).

Land use in the watershed has also been linked to the abundance and diversity of aquatic invertebrate communities. In Maryland Coastal Plain streams, King et al. (2005) found a high probability that land development within 820 feet of aquatic sampling stations would alter stream macroinvertebrate assemblages.

Most studies of effective buffer widths for amphibians come from literature on forest management. Buffers required for protecting amphibians from forest management practices differ by species and forest practice. Many amphibians also have partial or full terrestrial life stages and that require large continuous tracts of mature forest for foraging and dispersal as adults. In a timber management study on terrestrial and stream amphibians in Maine, amphibians were more abundant in forested buffers extending 36 to 49 feet from the stream than they were in adjacent clear cuts two years following harvest indicating some advantage to retaining buffers of this size (Perkins and Hunter, 2006). Partial tree harvest in the buffer did not appear to affect amphibian populations in this study.

In a study that tracked 123 California red-legged frogs from breeding ponds into their adult upland habitats, movement as far as 1.7 miles for one individual was observed (Fellers and Kleeman, 2007). At their study sites frogs moved primarily toward the nearest riparian area. The data from this amphibian movement and habitat use study indicate the importance of protecting habitat for breeding ponds, non-breeding forage sites, and migration corridors. The study authors recommend that buffers be designed to maintain the integrity of all three of these habitat components rather than as a set distance from a water body (Fellers and Kleeman, 2007). For instance, buffers adjacent to high intensity land uses such as urban development would be larger than those adjacent to agricultural land, or they may be wider in the direction of nearby breeding habitat.

4.3.5 Mammal Refugia and Movement

Mammals are an important part of the ecological food web and some species also play a role in the physical and biological processes of lakes and streams. The American beaver alters stream and pond environments due to its dam building habits. Some species, such as mice and voles, play important roles in seed dispersal and soil fertility (Cockle and Richardson, 2002). Six of the 29 species of mammals associated with riparian area on Island County are bats. Bats consume large quantities of insects each night as they feed over open water, and they roost beneath the bark of mature trees or in caves.

Most mammals found on Island County are relatively common, except for two species of bat, and most are found in a variety of habitats, rather than only in riparian areas. Several of the mammals are mid- to large-sized mammals that are wide ranging, generalist species such as black bear, black-tailed deer, and coyote. Maintaining enough undeveloped areas to support the prey base and movement patterns of these wide-ranging species is likely more important than the width of the riparian buffers.

Small mammal abundance and species diversity is affected by the condition and size of riparian buffers. In a forest management area in British Columbia, species richness was significantly lower in clearcuts than in 98-foot wide riparian forest buffers and in forested (unharvested) control areas (Cockle and Richardson, 2002). Differences in bot fly infestations were also noted in this study between clear-cut, retained buffer, and control forest, with no infestation in control areas, and more infestation in clear-cuts than in retained buffers (Cockle and Richardson, 2002).

A relationship between small mammal species diversity and riparian buffers is also found in grassland habitats. Along a cold water stream in Wisconsin, small mammal species diversity was significantly higher in retained grass buffers of 23 to 50 feet wide than in grazed grassland areas (Chapman and Ribic, 2002).

In Island County most small mammals are associated with upland forest and agricultural areas, so if these habitats remain connected to stream and lake areas, a contiguous riparian buffer may not be necessary to sustain native mammal populations (Table 2-1).

4.3.6 Bird Habitat

Riparian zones provide breeding habitat for more bird species than any other vegetation type in North America (Johnson and O'Neil, 2001). In Island County, at least 98 bird species are known to nest in stream riparian or open water habitats such as lakes. Bird species diversity and abundance in riparian buffers depends upon several factors, including but not limited to plant community composition, structural features, disturbance levels, riparian buffer width, and species requirements (Stacier, 2005).

Many of the birds in Island County that are associated with and breed in stream riparian areas are also associated with upland forest and agricultural habitats. Only a few species are closely associated with riparian areas, such as yellow warbler and warbling vireo (Table 2-1). Some birds are usually only found in riparian areas that are connected to larger forest tracts, but others are more adaptable in terms of their habitat needs. Forest-dwelling species such as band-tailed pigeon and Wilson's warbler are likely to require larger, undisturbed buffers than more generalist and edge-adapted species such as American robin and black-capped chickadee. Bird species that are well adapted to edge habitats, such as shrub borders surrounding agricultural areas, likely will be found in much narrower buffers than more specialized species, as long as adequate structure exists for nesting. Overall, the composition of bird communities in riparian buffers may be more related to the condition of plant communities, structure in the buffer, and land uses in the surrounding landscape than to buffer width in Island County.

Hanowski et al. (2005) surveyed changes in bird communities within 98-foot riparian buffers (control and three harvest treatments) located adjacent to a relatively small, 6 to 13-foot wide trout stream in northern Minnesota. Controls had no tree harvest in adjacent uplands or in the 98-foot buffer. The three treatments included no harvest, tree thinning and clear cut in the 98-foot buffer. The treatment buffers were surrounded by clear cut areas. Surveys conducted one year before and four years following harvest indicated that any harvest of trees adjacent to the 98-foot buffer or within the buffer caused changes in the bird species community composition that increased over time. The amount of change increased relative to the amount of disturbance within and outside of the buffer area. Their study suggests that a buffer wider than 98 feet is required for maintaining species associated with mature forest (Hanowski et al., 2005).

The need for wide tracts of undisturbed forest for some species is also apparent in other studies. Bird species dependent upon mature forest (or interior species) were found to decline two years after forest harvest in retained forest buffers up to 656 feet in width adjacent to lakes in Alberta (Hannon et al., 2002).

4.4 BAS Limitations – Habitat

Most recent studies on microclimate, stream temperatures, and wildlife habitat in riparian buffers are based on information from forest management scenarios comparing retained forest buffers with clear-cut conditions. There are some limitations on using this data for rural or suburban environments because some re-growth of forest is also occurring outside of re-established buffer areas. Also, most studies only compared one or two different buffer widths with clear-cuts and forested controls. The most common buffer width used in the studies reviewed was 98 feet, so widths smaller or larger than this were not captured in these studies. In addition, there are limitations to using these study results due to the relative short-term nature of these studies that span 10 years at the most. There may be longer term trends in plant and animal communities from changed habitat conditions thatn are not apparent in the first few years following forest harvest. The overall result is that we may be underestimating or overestimating the buffer areas required for maintaining native species populations in the long term.

5.0 SUMMARY FINDINGS

A wide range of effective buffer widths for various water quality and habitat functions is reported in the literature. This review of recent literature clearly indicates how myriad landscape and site-specific factors affect buffer functions. The high variability in study results regarding effective buffer widths aim us most appropriately to the use of variable buffer widths that depend upon key landscape and site conditions, including land use (Polyakov et al., 2005; Fellers and Kleeman, 2007).

Studies suggest that water quality functions can be achieved with optimal buffer design and site conditions with riparian buffers of approximately 33 feet. Buffers that meet this description are generally densely vegetated and positioned on relatively flat terrain. For Island County the NRCS office for the State of Washington recommends filter strips (vegetated buffers) of 20 feet to 40 feet to control sediment and nutrients during 24-hour storm events that occur on average once every 10 years (Adamus, 2007). Larger buffers of between 100 and 165 feet for water quality improvement are recommended in the literature for sites that require water quality treatment. However, Island County has low residential development overall, relatively high forest cover in many areas, and low loading of nutrients and sediments in streams according to preliminary monitoring data (Adamus, 2007; Adamus, 2006a). Given these general metrics, vegetated buffers less than 100 feet wide may provide adequate water quality treatment in Island County in most circumstances.

Employing appropriate BMPs, such as controlling erosion onsite, ensuring that septic systems are maintained, and managing the application of fertilizer and pesticides, can decrease the risk of pollutant and nutrient transport into streams and reduce riparian buffer widths needed to provide adequate water quality protection. Island County has regulations that require the use of BMPs during construction for all site developments and permanent water quality treatment systems for larger site developments. In addition, Island County is currently conducting a water quality monitoring program to identify sources of pollutants and take actions to eliminate or manage these sources to achieve water quality improvement and natural resource protection (Adamus et al., 2006a). All of these measures used by Island County to improve water quality in streams in lakes are also important for the receiving marine waters where so many habitats and species currently in decline in the region are sensitive to the impacts of pollution.

As with water quality treatment, buffer width cannot be considered as an independent factor without taking into account habitat quality and land use factors that influence fish and wildlife species inhabiting riparian buffers. Factors such as plant community composition, structure, and level of disturbance both near the stream and throughout the landscape play a critical role in providing suitable habitat for native species. Some wildlife species, like bird species dependent upon large areas of mature forest are not likely to be present even in forested buffers that are more than 656 feet wide. And many amphibian species require continuous forest cover for dispersal and for the terrestrial part of their life history.

Island County Code currently protects over 6,000 acres of habitat for migratory birds and waterfowl, this includes nine areas considered to be habitats of local importance. These protected areas also include habitat for many other species such as amphibians, wide-ranging mammals, invertebrates, and reptiles. Large patches of forest are also prevalent throughout Island County. Streams and lakes in these areas of Island County have continuous, vegetated buffers wide enough, sometimes more than 656 feet, to maintain a diversity of species and habitats, including the special status species listed on Table 1-3.

Table 2-3 lists wildlife species in Island County that are associated with both riparian and forest habitats. Many streams and lakes in other Island County basins are connected to large forest patches. Maintaining a continuous band of forest along these streams and lake borders is important for maintaining stream temperatures and for allowing the movement of animals between larger forest patches. Although buffers of more than 300 feet are recommended for maintaining a diversity of native wildlife species, forested buffers of 100 feet have been shown to maintain stream microclimate and water temperatures required by aquatic-dwelling species (Gomi et al., 2005; May, 2000; Sridhar et al., 2004).

Many generalist species, adapted to edge habitats, will be present even in highly disturbed, narrow buffer areas. Even some species of amphibian, such as red-legged frog, and stream invertebrates may be found in narrower buffers if their habitat requirements are met in areas surrounding the stream. However, species diversity and abundance generally increases with wider, less disturbed buffers, and many aquatic organisms will not survive without some amount of vegetated riparian buffers. Vegetated buffer widths demonstrated as effective in supporting a diversity of edge-adapted species ranged from about 25 feet to 100 feet.

The quality of a buffer is as important as the quantity of buffer. In Island County some areas, such as the Dugualla stream basin, are dominated by agricultural land uses and forest cover is limited to approximately 25% of the basin and only 5% of the total stream miles (Table 1-1). In these areas amphibian species that need the moist cover of forest for dispersal and other species that depend upon forest habitat are not likely to be found in buffer areas. The spread of invasive plant and wildlife species also degrades the quality of riparian buffers in Island County. Buffer regulations in basins areas with low forest cover, a high level of disturbance, or in urban areas could emphasize buffer restoration and enhancement with some flexibility in buffer width requirements in order to improve the conditions of streams and lakes in these areas. Meeting an overall goal to increase forested stream miles and forested basin area could be more important than the protection of wide, but degraded buffer areas.

Minimum buffer widths should be required to keep a base level of stream functionality in terms of microclimate, vegetation structure, and LWD. Minimum buffer widths should depend upon the habitat goals of the basin. Fish use in the basin should also be considered. Other western Washington jurisdictions have concluded during recent BAS reviews that buffer ranging from 100 to 165 feet in width are necessary for maintaining salmonid habitat functions in streams.

Many aquatic associated species including species of fish, stream invertebrates and amphibians depend upon intact forest cover adjacent to the stream for maintaining instream features important in their life cycles. The minimum recommended buffer width for maintaining stream habitat functions and characteristics, such as large wood recruitment, channel morphology, water temperature, and microclimate is cited in several studies and literature reviews as 100 feet.

Land cover and disturbance levels at the landscape scale are also important for maintaining stream features for native stream dwelling species. Stream morphology has been shown to change and stream ecosystems decline when impervious surfaces in stream basins exceed 10 percent (May et al., 1997). Because 93% of Island County is zoned as rural low density, one dwelling per five acres, it may be feasible to maintain and/or achieve a goal of having less than 10 percent impervious surfaces in many basins. Some flexibility with minimum buffers could be considered in basins where this goal of less than 10 percent impervious surfaces could be met, as long as another goal for maintaining a high level of forested cover is also part of this equation. The recently updated and adopted Island County wetland regulations address this opportunity for providing flexibility in buffer width requirements if sites are designed to minimize new impervious surfaces and other potential impacts to wetlands on the site. This type of site planning that emphasizes limiting the development footprint and use of LID techniques has potential to result in more comprehensive, long-term protection of natural resources throughout Island County.

6.0 REFERENCES

Abu-Zreig, M., R.P. Rudra, M.N. Lalonde, H.R. Whiteley, and N.K. Kaushik. 2004. *Experimental Investigation of Runoff Reduction and Sediment Removal by Vegetated Filter Strips*. Hydrological Processes. 18: 2029-2037. Published online 12 May 2004 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.1400.

Adamus, P.R. 2006a. *Draft Water Quality Data Synthesis and Recommendations for a Surface Freshwater Monitoring Program*. Adamus Resource Assessment, Inc., Water Resources Graduate Program, Oregon State University, Corvallis, OR, Island County Department of Planning and Community Development, Coupeville, WA, and Joe Eilers, Max Depth Aquatics, Bend, OR.

Adamus, P.R., J. Burcar, K. Harma, C. Luerkens, A. Boscolo, J. Coleman, and M. Kershner. 2006b. *Wetlands of Island County, Washington: Profile of Characteristics, Functions, and Health.* Report to Island County Dept. of Planning & Community Development, Coupeville, WA.

Adamus, P.R. 2007. *Best Available Science for Wetlands of Island County, Washington: Review of Published Literature: A Report Prepared in Response to Critical Areas Ordinance Updating Requirements for Wetlands*. Adamus Resource Assessment, Inc. and College of Oceanic and Atmospheric Sciences, Oregon State University.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. *Stream temperature and aquatic habitat: Fisheries and forestry interactions*. Pages 191 to 232 in Salo, E.O., and T.W. Cundy (ed) Streamside management: Forestry and fishery interactions. Contribution 57. University of Washington, Seattle, Washington.

Binford, M.W. and M.J. Bucheneau. 1993. *Riparian greenways and water resources*. *In*: Smith, D.S. and P. Cawood, editors. Ecology of Greenways, University of Press. Minneapolis, Minnesota.

Broadmeadow, S. and T.R. Nisbet. 2004. *The Effects of Riparian Forest Management on the Freshwater Environment: a Literature Review of Best Management Practice*. Hydrology and Earth System Sciences, 8(3), 286-305.

Chapman, E.W. and C.A. Ribic. 2002. *The Impact of Buffer Strips and Stream-Side Grazing on Small Mammals in Southwestern Wisconsin*. Agriculture, Ecosystems and Environment. 88:49-59.

Cockle, K.L. and J.S. Richardson. 2003. *Do Riparian Buffer Strips Mitigate the Impacts of Clearcutting on Small Mammals?* Biological Conservation. 113:133-140.

Elliott, L. 2003. *A New Approach to Quantifying Riparian Buffers in the Rural-Urban Fringe in the Lower Fraser Valley*. 2003 Georgia Basin/Puget Sound Research Conference.

Fellers, G.M. and P.M. Kleeman. 2007. *California Red-Legged Frog (Rana draytonii) Movement and Habitat Use: Implications for Conservation*. Journal of Herpetology. 14(2): 276-286.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. *Forest ecosystem management: an ecological, economic, and social assessment*. U.S. Departments of Agriculture, Commerce, and Interior. Portland Oregon.

Gomi, T., R. D. Moore, and Am.S. Dhakal. 2006. *Headwater Stream Temperature Response to Clear-cut Harvesting with Different Riparian Treatments, Coastal British Columbia, Canada*. Water Resources Research. Vol. 42, W08437, doi:10.1029/2005WR004162.

Hannon, S.J. C.A. Paszkowski, S. Boutin, J. DeGroot, S.E. Macdonald, M. Wheatley, and B.R. Eaton. 2002. *Abundance and Species Composition of Amphibians, Small Mammals, and Songbirds in Riparian Forest Buffer Strips of Varying Widths in the Boreal Mixedwood of Alberta. Canadian Journal of Forest Research*.32:1784-1800.

Hanowski, J., N. Danz, J. Lind, and G. Niemi. 2005. *Breeding Bird Response to Varying Amounts of Basal Area Retention in Riparian Buffers*. Journal of Wildlife Management. 69(2): 689-698.

Hruby, T. 2004. *Washington State Wetland Rating System, Western Washington.* Washington State Department of Ecology. Olympia, WA.

Johnson, R. E., and K. M. Cassidy. 1997. *Mammals of Washington state: location data and modeled distributions*. Washington State GAP Analysis, Volume 3. Washington Cooperative Fish and Wildlife Research Unit, Seattle, Washington, USA.

Johnson, D.H. and T.A. O'Neil. 2001. *Wildlife-Habitat Relationships in Oregon and Washington*. Oregon State University Press. Corvallis, Oregon. 736 pp.

Lowrance, R. and J.M. Sheridan. 2005. *Surface Runoff Water Quality in a Managed Three Zone Riparian Buffer*. Journal of Environmental Quality. 34:1851-1859.

King, R.S., M.E. Baker, D.F. Whigham, D.E. Weller, T.E. Jordan, P.R> Kazyak, and M.K. Hurd. 2005. *Spatial Considerations for Linking Watershed Land Cover to Ecological Indicators in Streams*. Ecological Applications. 15(1): 137-153.

Knutson, K.L. and V.L. Naef. 1997. *Management Recommendations for Washington's Priority Habitats: Riparian*. Washington Department of Fish and Wildlife, Olympia, Washington. 181pp.

Madden, S.S., Robinson, G.R., and J.G. Arnason. 2007. *Spatial Variation in Stream Water Quality in Relation to Riparian Buffer Dimensions in a Rural Watershed of Eastern New York State*. Northeastern Naturalist. 14(4): 605-618.

Mankin, K.R., D.M. Ngandu, C.J. Barden, S.L. Hutchinson, and W.A. Geyer. 2007. *Grass-Shrub Riparian Buffer Removal of Sediment, Phosphorus, and Nitrogen from Simulated Runoff*. Journal of the American Water Resources Association (JAWRA). 43(5):1108-1116. DOI:10.1111/j.1752-1688.2007.0090.x.

May, C. W., R. R. Horner, J. R. Karr, B. W. Mar, and E. B. Welch. 1997. *Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion*. Watershed Protection Techniques Vol. 2, No. 4.

May, C.W. 2000. *Protection of Stream-Riparian Ecosystems: a Review of Best Available Science*. Prepared for Kitsap County Natural Resources Coordinator. July 2000.

Mayer, P.M., S.K. Reynolds, McCutchen, and T.J. Canfield. 2005. *Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations*. EPA/600/R-05/118. Cincinnati, Ohio, U.S. Environmental Protection Agency.

Mayer, P.M., S.K. Reynolds, Jr. Marshall, D. McCutchen, and T.J. Canfield. 2007. *Meta-Analysis of Nitrogen Removal in Riparian Buffers*. Journal of Environmental Quality. 36: 1172-1180.

Meleason, M.A. and J.M. Quinn. 2004. *Influence of Riparian Buffer Width on Air Temperature at Whangapoua Forest, Coromandel Peninsula, New Zealand*. Forest Ecology and Management 191: 365-371. Available online at www.sciencedirect.com.

Naiman, R.J., and R.E. Bilby. 1998. *River ecology and management in the Pacific Coastal Ecoregion*. *In:* Naiman, R.J. and R.E. Bilby, editors, River ecology and management: Lessons from the Pacific coastal ecoregion. Springer-Verlag, New York, New York.

Naiman, R.J., H. Decamps, and M.E. McClain. 2005. *Riparia: Ecology, Conservation, and Management of Streamside Communities*. Elsevier Academic Press.

Ness, A.O. and C.G. Richins. 1958. *Soil Survey of Island County, Washington*. United States Department of Agriculture, Soil Conservation Service in cooperation with Washington Agricultural Experiment Station, Institute of Agricultural Science, State College of Washington.

Parametrix, Adolfson Associates, Earth Systems, Coastal Geologic Services, Jennifer Thomas & Associates. 2005. *Whatcom County Critical Areas Ordinance: Best Available Science Review and Recommendations for Code Update*. Prepared for Whatcom County Planning and Development Services, Bellingham, Washington.

Parkyn, S. 2004. *Review of Riparian Buffer Zone Effectiveness*. Canada Ministry of Agriculture and Forestry (MAF). Technical Paper No: 2004/05.

Perkins, D.W. and M.L. Hunter. 2006. *Effects of Riparian Timber Management on Amphibians in Maine*. Journal of Wildlife Management. 70(3): 657-670.

Polyakov, V. A. Fares, and M.H. Ryder. 2005. *Precision Riparian Buffers for the Control of Nonpoint Source Pollutant Loading into Surface Water: A Review*. Environmental Review. 13: 129-144. Published on the NRC Research Press Web site at http://er.nrc.ca/ on 16 August 2005.

Roodsari, R.M. D.R. Shelton, A. Shirmohammadi, Y.A. Pachepsky, A.M. Sadeghi, and J.L. Starr. 2005. Transactions of the American Society of Agricultural Engineers. Vol. 48(3): 1055-1061.

Salmon Recovery Plan Technical Advisory Group: WRIA 6 (SRP). 2005. *WRIA 6 (Whidbey and Camano Islands) Multi-Species Salmon Recovery Plan*. Adopted by the Island County Water Resources Advisory Committee and Board of Island County Commissioners.

Schultz, R. C., T.M. Isenhart, W.W. Simpkins, and J.P. Colletti. 2004. *Riparian Forest Buffers in Agroecosystems – Lessons Learned from the Bear Creek Watershed, Central Iowa, USA*. Agroforestry Systems 61: 35-50. Printed in the Netherlands.

Seattle Audubon Society. 2008. *BirdWeb*. Accessed at http://www.birdweb.org/birdweb/bird_details.aspx?id=321#wa_map on October 20, 2008.

Shared Strategy for Puget Sound Development Committee. 2007. *Puget Sound Salmon Recovery Plan Volume 1*. Available: http://www.sharedsalmonstrategy.org/plan/.

Smith, M.R., P.W. Mattocks, Jr., and K.M. Cassidy. 1997. *Breeding Birds of Washington State*. Volume 4 *in* Washington State Gap Analysis – Final Report (K.M. Cassidy, C.E. Grue, M.R. Smith, and K.M. Dvornich, eds.). Seattle Audubon Society Publications in Zoology No. 1, Seattle, 538 pp.

Sridhar, V. A.L. Sansone, J. LaMarche, T. Dubin, and D.P. Lettenmaier. 2004. *Prediction of Stream Temperature in Forested Watersheds*. Journal of the American Water Resources Association (JAWRA) 40(1): 197-213.

Staicer, D. 2005. *The Role of Riparian Buffers in Forest Bird Conservation*. RES04-09. Final Report to the Nova Forest Alliance 2004-2005.

Vidon, P.G.F. and A.R. Hill. 2004. *Landscape Controls on Nitrate Removal in Stream Riparian Zones*. Water Resources Research. Vol. 40, W03201, doi:10.1029/2003WR002473.

Washington State Department of Ecology (WDOE). 2005. *Habitat Limiting Factors: Water Resource Inventory Area (WRIA) 6 Island County: Executive Summary*. Accessed at http://salmon.scc.wa.gov/reports/wria06sum.shtml. On April 1, 2008.

Washington State Department of Fish and Wildlife (WDFW). 2008. *Priority Species and Habitat Lists and StreamNet database*. Olympia, Washington.

Washington State Department of Natural Resources (WDNR). 2001. *Washington State ShoreZone Inventory*. Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, Washington.

Washington State Department of Natural Resources (WDNR). 2008. *List of Known Occurrences of Rare Plants in Washington State. February 2008. Island County*. Accessed at http://www1.dnr.wa.gov/nhp/refdesk/lists/plantsxco/island.html on October 20, 2008.

Washington Trout. 2006. *Island County Creek Restoration Planning 2003-2004.* Accessed at: http://www.washingtontrout.org/islandco/index.shtml. On June 5 and October 3, 2008.

Wenger, S. 1999. *A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation*. Office of Public Service and Outreach, Institute of Ecology, University of Georgia.

Zelo, I. and H. Shipman. 2000. *Alternative bank protection methods for Puget Sound shorelines*. Shorelands and Environmental Assistance Program, Washington Department of Ecology, Olympia, Washington. 130pp.

FIGURES

This Page Intentionally Left Blank

ISLAND COUNTY

Department of Planning & Community Development

Anadromous and Resident Fish Basins and Streams

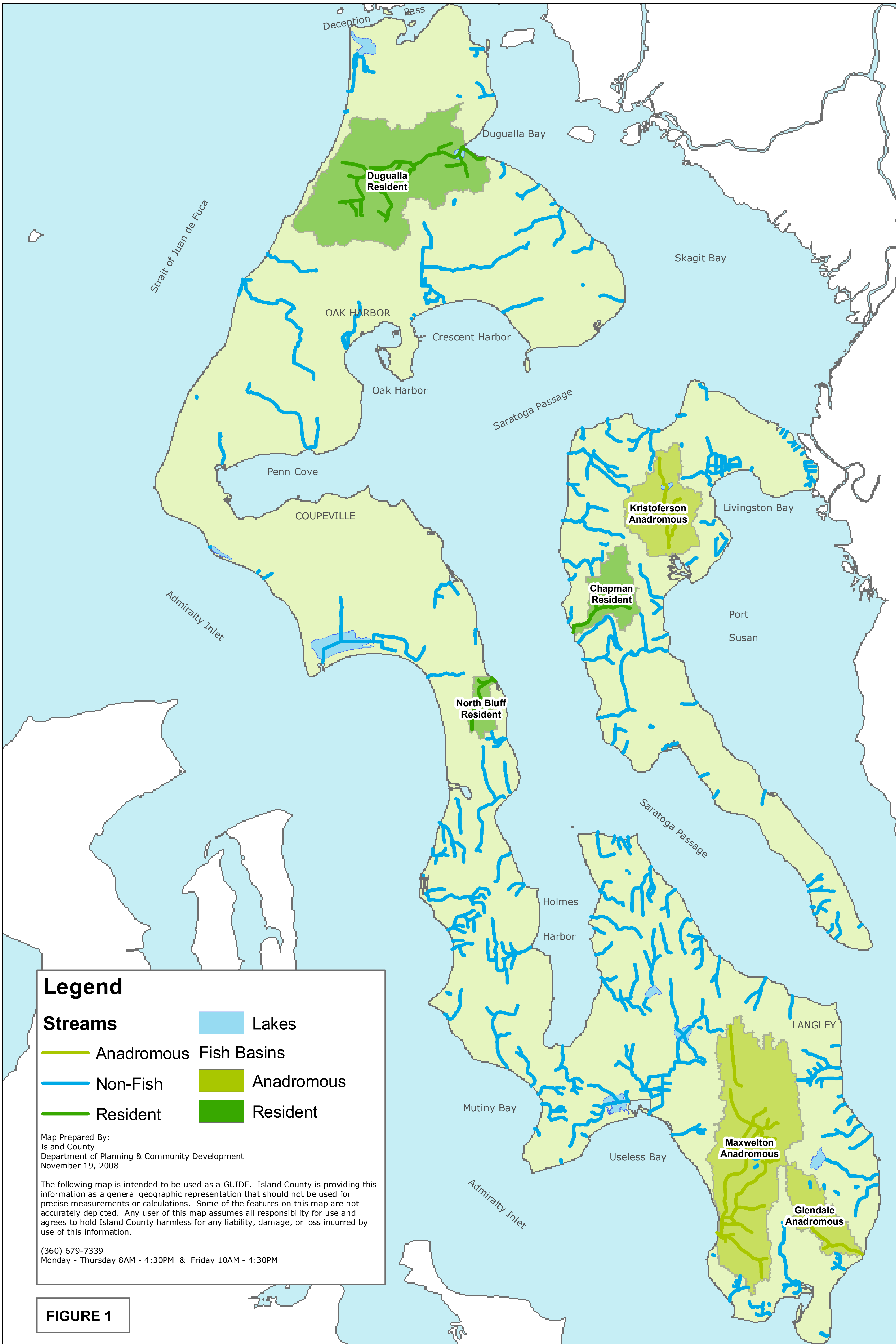

FIGURE 1

ISLAND COUNTY

Department of Planning & Community Development

Basins

FIGURE 2

APPENDIX A: VERTEBRATES DOCUMENTED IN ISLAND COUNTY, WA
Compiled by Paul Adamus, October 14, 2008

VERTEBRATES DOCUMENTED IN ISLAND COUNTY, WA

Compiled by Paul Adamus, October 14, 2008

AMPHIBIANS & REPTILES of Island County

SciName	Common Name	Camano	Whidbey
Ambystoma gracile	Northwestern salamander		X
Ambystoma macrodactylum	long-toed salamander	X	X
Taricha granulosa	roughskin newt	X	X
Ensatina eschscholtzii	ensatina	X	X
Bufo boreas	western toad	X	X
Hyla regilla	Pacific treefrog	X	X
Rana aurora	red-legged frog	X	X
Rana catesbeiana	bullfrog	X	X
Elgaria coerulea	northern alligator lizard	X	X
Charina bottae	rubber boa	X	X
Thamnophis elegans	western terrestrial garter snake	X	X
Thamnophis ordinoides	northwestern garter snake	X	X
Thamnophis sirtalis	common garter snake	X	X

MAMMALS of Island County

C= confirmed; **M**= modeled by Johnson & Cassidy 1997;
blank= occurs on nearby mainland but no known records in Island County

SciName	**Common Name**	**Camano**	**Whidbey**
Sorex cinereus	Masked shrew		
Sorex monticolus	Montane shrew		
Sorex trowbridgii	Trowbridge's shrew		
Sorex vagrans	Vagrant shrew	M	M
Neurotrichus gibbsii	Shrew-mole		
Scapanus orarius	Coast mole		
Eptesicus fuscus	Big brown bat		C
Lasionycteris noctivagans	Silver-haired bat		C?
Lasiurus cinereus	Hoary bat	C	
Myotis californicus	California myotis		
Myotis evotis	Long-eared myotis		C
Myotis keenii	Keen’s myotis		M
Myotis lucifugus	Little brown bat		
Corynorhinus townsendii	Townsend's big-eared bat		C
Canis latrans	Coyote		C
Vulpes vulpes	Red fox	M	C
Procyon lotor	Raccoon	C	C
Ursus americanus	Black bear		C
Mephitis mephitis	Striped skunk		
Mustela frenata	Long-tailed weasel	M	M
Lutra canadensis	River otter	M	C
Odocoileus hemionus	Mule deer	C	C
Aplodontia rufa	Mountain beaver		
Glaucomys sabrinus	Northern flying squirrel		
Castor canadensis	American beaver	C	C
Tamias townsendii	Townsend's chipmunk		C
Tamiasciurus douglasii	Douglas' squirrel		C
Clethrionomys gapperi	Southern red-backed vole		
Microtus longicaudus	Long-tailed vole		
Microtus montanus	Montane vole		
Microtus oregoni	Creeping vole		C
Microtus townsendii	Townsend's vole	M	M
Ondatra zibethicus	Muskrat	M	C
Mus musculus	House mouse		
Neotoma cinerea	Bushy-tailed woodrat		
Peromyscus maniculatus	Deer mouse	M	C
Rattus norvegicus	Norway rat	M	C
Zapus trinotatus	Pacific jumping mouse		
Erethizon dorsatum	Porcupine		
Oryctolagus cuniculus	European rabbit		C
Sylvilagus floridanus	Eastern cottontail		C

BIRDS of Island County, excluding accidental occurrences
W= typically on or within a few feet of water in a lake, beach, wetland, or estuary
WE= stronger association with estuarine or marine waters in Island County
L= typically on land (generally)
LR= mostly land, but somewhat associated with riparian land (near water) in Island County
C= common, U= uncommon, O= occasional, R= rare, A= accidental
N= nests, P= possibly nests but unconfirmed

				SEASON				
	Lake/ Estuary	Stream Perenn	Stream Ephem	Spr	Su	F	W	Status
Red-throated Loon	WE			C	O	C	C	
Pacific Loon	WE			C	U	C	C	
Common Loon	WE			C	U	C	C	
Yellow-billed Loon	WE			O	R	O	O	
Pied-billed Grebe	W			U	U	U	U	N
Horned Grebe	WE			C	R	C	C	
Red-necked Grebe	WE			C	O	C	C	
Eared Grebe	WE			U	R	U	U	
Western Grebe	WE			C	O	C	C	
Clark's Grebe	WE			O		O	O	
Double-crested Cormorant	W			C	C	C	C	N
Brandt's Cormorant	WE			C	O	C	C	
Pelagic Cormorant	WE			C	C	C	C	
American Bittern	W			U	U	U	P	
Great Blue Heron	W	W		C	C	C	C	N
Great Egret	W				A	R		
Tundra Swan	W			O		O	O	
Trumpeter Swan	W			O		O	O	
Greater White-fronted Goose	W			O	A	O	R	
Snow Goose	W			R		R	R	
Brant	WE			C	R	U	U	
Canada Goose	W			C	C	C	C	N
Wood Duck	W	W,L		U	U	U		N
Green-winged Teal	W			C	U	C	C	N
Mallard	W	W		C	C	C	C	N
Northern Pintail	W			C	U	C	C	P
Blue-winged Teal	W			U	O	O		N
Cinnamon Teal	W			U	U	O		N
Northern Shoveler	W			C	O	U	C	N
Gadwall	W			C	C	C	C	N
Eurasian Wigeon	W			U		U	U	
American Wigeon	W			C	O	C	C	N
Canvasback	W			U		U	U	
Redhead	W					R	R	
Ring-necked Duck	W			U		U	U	
Greater Scaup	W			C		C	C	
Lesser Scaup	W			C	O	C	C	N
Harlequin Duck	WE			C	C	C	C	

				SEASON				
	Lake/ Estuary	Stream Perenn	Stream Ephem	Spr	Su	F	W	Status
Long-tailed Duck	WE			O	O	O	C	
Black Scoter	WE			O	R	O	C	
Surf Scoter	WE			C	C	C	C	
White-winged Scoter	WE			C	U	C	C	
Common Goldeneye	W			C		C	C	
Barrow's Goldeneye	W			C		C	C	
Bufflehead	W			C	R	C	C	
Hooded Merganser	W			U	O	U	U	N
Common Merganser	W			O		O	O	
Red-breasted Merganser	WE			C	R	C	C	
Ruddy Duck	W			C	U	C	C	N
Turkey Vulture	L	L	L	O	U	R		
Osprey	LR, W	LR, W		U	U	U	R	N
Bald Eagle	LR, W	LR, W		C	C	C	C	N
Northern Harrier	LR	LR	LR	C	C	C	C	N
Cooper's Hawk	L	L	L	U	U	U	U	N
Sharp-shinned Hawk	L	L	L	U	R	U	U	N
Northern Goshawk	L	L	L				R	
Red-tailed Hawk	L	L	L	C	C	C	C	N
Rough-legged Hawk	L	L	L	O		U	U	
Golden Eagle	L	L	L	O	O	O	O	
American Kestrel	L	LR	LR	O	O	O	O	P
Merlin	L	LR	LR	U	R	U	U	
Peregrine Falcon	LR	LR		U	U	U	U	
Ring-necked Pheasant	L	L	L	U	U	U	U	P
California Quail	L	L	L	C	C	C	C	N
Virginia Rail	W	W		U	U	U	O	N
Sora	W	W		O	O			N
American Coot	W			C	C	C	C	N
Black-bellied Plover	WE			O	O	U	U	
Pacific Golden-Plover	WE					O		
American Golden-Plover	WE					O		
Semipalmated Plover	WE			O	O	U		
Killdeer	W	W		C	C	C	C	N
Black Oystercatcher	WE			U	O	U	C	
Willet	WE				A	R		
Greater Yellowlegs	WE			C	U	C	U	
Lesser Yellowlegs	WE			U	U	U		
Solitary Sandpiper	W			R		R	R	
Spotted Sandpiper	W	W		U	O	U	R	
Whimbrel	WE			O	R	U		
Long-billed Curlew	WE			R	O	R		
Marbled Godwit	WE					R		
Ruddy Turnstone	WE			O	O	O		
Black Turnstone	WE			C	O	C	C	
Surfbird	WE			U	O	U	U	

				SEASON				
	Lake/ Estuary	Stream Perenn	Stream Ephem	Spr	Su	F	W	Status
Red Knot	WE					R		
Sanderling	WE			U	R	U	C	
Semipalmated Sandpiper	WE			R	U	U		
Western Sandpiper	WE			C	C	C	U	
Least Sandpiper	WE			C	C	C		
Baird's Sandpiper	WE			O		R	O	
Pectoral Sandpiper	WE			R	R	O		
Rock Sandpiper	WE			O		O	O	
Dunlin	WE			C	R	C	C	
Stilt Sandpiper	WE					O		
Sharp-tailed Sandpiper	WE				A	R		
Ruff	WE					R		
Short-billed Dowitcher	WE			O	C	C		
Long-billed Dowitcher	WE			O	C	C	R	
Wilson's Snipe	W	W		U	U	U		N
Wilson's Phalarope	WE					O		
Red-necked Phalarope	WE				U	O		
Parasitic Jaeger	WE			A		O		
Bonaparte's Gull	WE			C	U	C	C	
Heermann's Gull	WE				C	C	R	
Franklin's Gull	WE				R	O		
Mew Gull	W			C	O	C	C	
Ring-billed Gull	W			C	U	C	C	
California Gull	W			O	C	C	R	
Herring Gull	W			U	A	O	U	
Thayer's Gull	W			O		O	O	
Glaucous-winged Gull	W			C	C	C	C	N
Western Gull	W			O	R	O	O	
Glaucous Gull	WE			R		R	R	
Caspian Tern	WE			C	C	C		N
Common Tern	WE			O	R	C		
Elegant Tern	WE					R		
Common Murre	WE			U	U	U	U	
Pigeon Guillemot	WE			C	C	C	C	N
Marbled Murrelet	WE			U	U	U	U	
Ancient Murrelet	WE					O		
Rhinoceros Auklet	WE			C	C	C	C	
Tufted Puffin	WE				R			
Rock Dove	L	L	L	C	C	C	C	N
Band-tailed Pigeon	L	L	L	U	U	U	O	N
Mourning Dove	L	L	L	C	C	C	U	N
Barn Owl	L	L	L	U	U	U	O	N
Western Screech-Owl	LR	LR	LR	R	R	R	R	N
Great Horned Owl	L	L	L	C	C	C	C	N
Snowy Owl	L	L	L			R	R	
Northern Pygmy-Owl	L	L	L	O	O	O	O	

				SEASON				
	Lake/ Estuary	Stream Perenn	Stream Ephem	Spr	Su	F	W	Status
Barred Owl	L	L	L	C	C	C	C	N
Short-eared Owl	LR	LR	LR	U	R	U	U	N
Northern Saw-whet Owl	L	L	L	O	O	O	O	N
Common Nighthawk	L	L	L	U	U			P
Black Swift	L	L	L	R		A		
Vaux's Swift	L	L	L	R		R		
Anna's Hummingbird	L	L	L	R	R	R	R	
Rufous Hummingbird	L	L	L	C	C	O	R	N
Belted Kingfisher	W, LR	W, LR		C	C	C	C	N
Red-breasted Sapsucker	L	L	L	O	R	O	O	N
Downy Woodpecker	L	L	L	C	C	C	C	N
Hairy Woodpecker	L	L	L	C	C	C	C	N
Northern Flicker	L	L	L	C	C	C	C	N
Pileated Woodpecker	L	L	L	U	U	U	U	N
Olive-sided Flycatcher	L	L	L	U	U	U		N
Western Wood-Pewee	L	L	L	R	U	U		P
Willow Flycatcher	LR	LR	LR	U	U	U		P
Hammond's Flycatcher	L	L	L	O	O	O		
Pacific-slope Flycatcher	L	L	L	C	C	C		N
Western Kingbird	L	L	L	O				
Northern Shrike	L	L	L	O		O	O	
Hutton's Vireo	L	L	L	U	U	U	U	N
Cassin's Vireo	L	L	L	O	O			N
Red-eyed Vireo	L	L	L	R		R		
Warbling Vireo	LR	LR	LR	U	U	U		N
Steller's Jay	L	L	L	U	U	U	U	N
American Crow	L, W	L, W	L, W	C	C	C	C	N
Common Raven	L, W	L, W	L, W	U	U	U	U	N
Horned Lark	L	L	L	R		O		
Tree Swallow	LR, W	LR, W	LR, W	C	C	U		N
Purple Martin	LR, W			R	R	R		
Violet-green Swallow	LR	LR	LR	C	C	C		N
Rough-winged Swallow	LR	LR	LR	C	C	C		N
Bank Swallow	LR	LR	LR			O		
Cliff Swallow	LR	LR	LR	C	C	C		N
Barn Swallow	LR	LR	LR	C	C	C		N
Black-capped Chickadee	L	L	L	U	U	U	U	N
Chestnut-backed Chickadee	L	L	L	C	C	C	C	N
Bushtit	L	L	L	U	U	U	U	N
Brown Creeper	L	L	L	C	C	C	C	N
Red-breasted Nuthatch	L	L	L	C	C	C	C	N
Bewick's Wren	L	L	L	U	U	U	U	N
House Wren	L	L	L	U	U	U	A	N
Winter Wren	L	L	L	C	U	C	C	N
Marsh Wren	W			C	C	C	U	N
Golden-crowned Kinglet	L	L	L	C	U	C	C	N

				SEASON				
	Lake/ Estuary	Stream Perenn	Stream Ephem	Spr	Su	F	W	Status
Ruby-crowned Kinglet	L	L	L	C		C	C	
Mountain Bluebird	L	L	L	R		A		
Townsend's Solitaire	L	L	L	R		R	R	
Swainson's Thrush	LR	LR	LR	C	C	U		N
Hermit Thrush	L	L	L	U		U	R	
Varied Thrush	L	L	L	C	R	C	C	P
American Robin	L	L	L	C	C	C	C	N
European Starling	L	L	L	C	C	C	C	N
American Pipit	W,LR	W,LR	W,LR	O		U	R	
Bohemian Waxwing	L	L	L			R		
Cedar Waxwing	L	L	L	C	C	C	R	N
Orange-crowned Warbler	L	L	L	C	C	U	O	N
Yellow Warbler	LR	LR	LR	C	C	U		N
Yellow-rumped Warbler	L	L	L	C	O	C	O	N
Black.-throated Gray Warbler	L	L	L	U	U	O		N
Townsend's Warbler	L	L	L	C	U	U	R	N
MacGillivray's Warbler	L	L	L	R		R		
Common Yellowthroat	W,LR	W,LR	W,LR	C	C	C		N
Wilson's Warbler	L	L	L	C	C	U		N
Western Tanager	L	L	L	U	U	U		N
Spotted Towhee	L	L	L	C	C	C	C	N
Chipping Sparrow	L	L	L	R		R		
Savannah Sparrow	L	L	L	C	C	C	O	N
Fox Sparrow	L	L	L	C		C	C	
Song Sparrow	LR	LR	LR	C	C	C	C	N
Lincoln's Sparrow	LR	LR	LR	U		U	O	
White-throated Sparrow	L	L	L			R	R	
Golden-crowned Sparrow	L	L	L	C		C	C	
White-crowned Sparrow	L	L	L	C	C	C	U	N
Dark-eyed Junco	L	L	L	C	C	C	C	N
Lapland Longspur	L	L	L	A		O		
Snow Bunting	L	L	L			O		
Black-headed Grosbeak	L	L	L	U	U	U		N
Western Meadowlark	L	L	L	U	O	U	U	P
Yellow-headed Blackbird	W			O	O	O		N
Red-winged Blackbird	LR	LR	LR	C	C	C	C	N
Brewer's Blackbird	L	L	L	C	C	C	C	N
Brown-headed Cowbird	L	L	L	C	C	C	O	N
Purple Finch	L	L	L	U	O	O	U	P
House Finch	L	L	L	C	C	C	C	N
Red Crossbill	L	L	L	U	O	U	U	N
Pine Siskin	L	L	L	C	U	C	C	N
American Goldfinch	L	L	L	C	C	C	O	N
Evening Grosbeak	L	L	L	U	R	O	R	P
House Sparrow	L	L	L	C	C	C	C	N