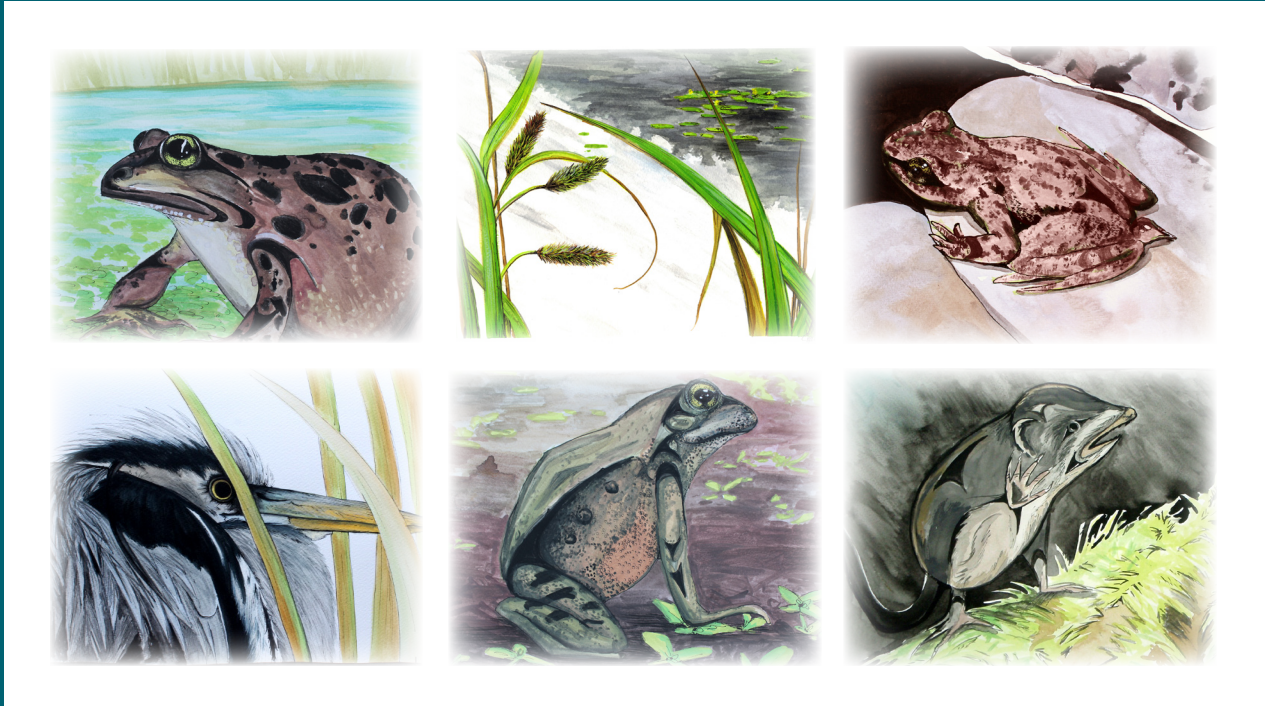


DIVERSITY by DESIGN



Restoring Habitat for Species at Risk on BC's South Coast Module 3 - Stream and Riparian Communities



SOUTH COAST CONSERVATION PROGRAM

Protecting and Restoring at Risk species and Ecological Communities on BC's South Coast



South Coast Conservation Program
www.sccp.ca

Established in 2005, the South Coast Conservation Program (SCCP) is a multi-partner, landscape-level conservation program. The SCCP was established to provide a coordinated approach and facilitate implementation of sound conservation and management for species and ecosystems at risk within the South Coast region.

Partners in the SCCP include the provincial and federal governments, municipalities, regional districts, First Nations, non-government conservation organizations and programs, universities, and several private consultants.

*For more information on the SCCP, including a full list of organizational partners, visit:
www.sccp.ca
Email: info@sccp.ca*

*For more information on the Species at Risk Act (SARA) and legal and regulatory obligations please check out "SARA and You".
<https://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=6AC53F6B-1>
E-mail: SARAreistry@ec.gc.ca*

*For individuals wishing information on SARA permits, the following website includes information on permitting, including an application and relevant contact information.
<http://www.dfo-mpo.gc.ca/species-especes/permits-permis/permits-eng.htm>*

*Province of BC: Contact the Ecosystems and Sustainability Branch
<http://www.env.gov.bc.ca/wld/>
E-mail wildlife@victoria1.gov.bc.ca*

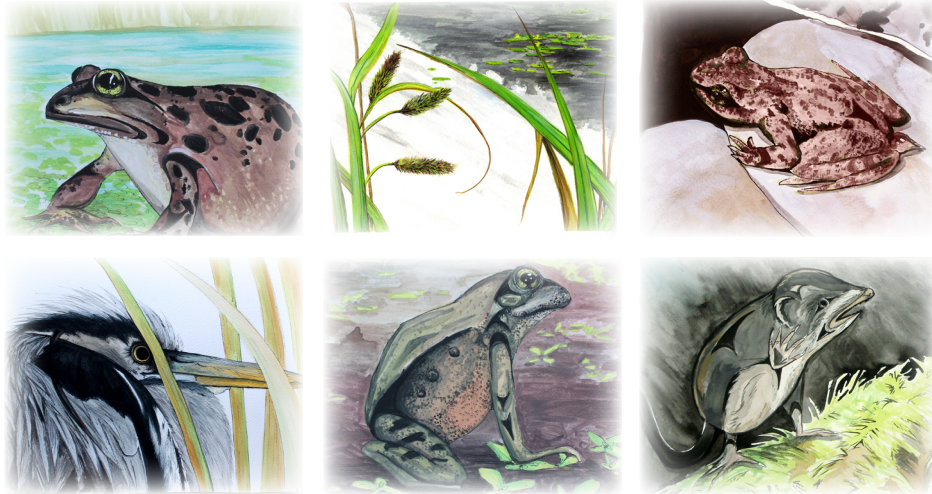
Part of the National Conservation Plan, this project was undertaken with the financial support of the Government of Canada. Dans le cadre du Plan de conservation national, ce projet a été réalisé avec l'appui financier du Gouvernement du Canada:



Canada

*Cover illustrations by Carrielynn Victor.
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Diversity by Design



A Guide to Restoring Habitat for Species at Risk on BC's South Coast Module 3 - Stream and Riparian Communities

Developed in collaboration with Diamond Head Consulting.
Primary Authors for the original draft modules were J. Brett Allen and Michael Coulthard, with support from Fiona Steele and Edward Porter (all of Diamond Head Consulting).

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August 2015



ACKNOWLEDGEMENTS

This project would not have been possible without the contributions of Dr. Mike Pearson RPBio (Pearson Ecological).

Special Thanks to Diamond Head Consulting for their expertise and assistance in developing the content of this project.



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1. OVERVIEW



Great Blue Heron - Illustration by Carrielynn Victor

British Columbia's South Coast region¹ is one of the most populated and biologically rich regions in Canada. Over two million people call the region home, in addition to a diversity of plants, animals and other organisms. However, human activities such as urban development, agriculture and forestry have had significant impacts to the region's natural habitat and the species that depend on it. Today, there are over 260 species of plants and animals provincially and/or federally listed as threatened or endangered in the South Coast region.

The South Coast Conservation Program (SCCP) works to assist stakeholders, including government, conservation groups, land use interests and local communities, to conserve species and ecosystems at risk. In support of the SCCP's mandate, Diversity by Design was developed to assist in the planning, implementation and monitoring of habitat restoration projects. The objective of this program is to promote a multi-species approach to restoration with a particular focus on species at risk. Together with the other two modules – Wetland Communities and Forest Communities, "Stream Communities" complements the main guidebook developed in 2013 by Patrick Lilley. It also supports the work of the SCCP's partners including the Stewardship Centre of BC's Species at Risk Voluntary Stewardship Practices for: Riparian Areas in Settled Landscapes, one of series of



Figure 1. Diversity by Design Toolkit.

¹ The South Coast region includes five regional districts: Fraser Valley, Metro Vancouver, Powell River, Sunshine Coast, and Squamish-Lillooet.

OVERVIEW

best management practices developed as part of the Species at Risk Primer Program.² The Diversity by Design toolkit is a holistic approach to habitat restoration and enhancement for species and ecological communities at risk on BC's South Coast.

Each module explains important concepts to guide preparation of effective habitat restoration prescriptions. They will help audiences to identify restoration goals, implement current best management practices and avoid unforeseen challenges. Case studies are included to demonstrate successful application of restoration principles in real world, local situations.



Coquitlam River sidechannel. Photo: Pamela Zevit.

Ecological Communities

Natural plant communities and plant associations that are a function of climate, soil, physiography, and nutrient/energy flows.

Species and Ecological Communities at Risk

Species and ecological communities are considered at “risk” if they are extirpated, endangered or threatened in British Columbia, or are considered to be of special concern (i.e. sensitive to human disturbance, which may cause them to be endangered or threatened).³

² <http://www.stewardshipcentrebc.ca/species-at-risk-primer>.

³ BC Conservation Data Centre <http://www.env.gov.bc.ca/cdc/> *While the SCCP integrates species of conservation concern at the regional and provincial levels into its work (i.e. Provincially Red and Blue listed species), particular emphasis is on species listed under the Federal Species At Risk Act. Species listed in the Diversity By Design series may fall into various jurisdictional listing categories.

OVERVIEW

1.1 Who should use this guide?

Diversity by Design is intended for those who may not have an extensive technical background in ecological restoration. The guide and modules provide a roadmap for a range of potential interests wanting to undertake restoration projects that will benefit species and ecological communities at risk. Information in this module can be used by a wide audience including government agencies, non-governmental organizations, habitat stewardship groups, developers, and private landowners.

1.2 Where to find other sources of information

Diversity by Design provides a variety of information, there is however a vast amount of other web and print based material that can be consulted as more detailed guidance is required. All are available online and many are linked through the SCCP's website.

Some of these include:

- Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia. Ministry of Environment. 2014.
- Ministry of Water Land and Air Protection. Riparian Areas Regulation Implementation Guidebook. 2006.
- Standards and Best Practices for Instream Works. Ministry of Water Land and Air Protection. 2004.
- Fish Stream Crossing Guidebook. Ministry of Forests. 1998
- Land Development Guidelines for the Protection of Aquatic Habitat. Department of Fisheries and Oceans. 1993.
- Species at Risk Voluntary Stewardship Practices for Riparian Areas in Settled Landscapes. Stewardship Centre for British Columbia. 2013.
- Species at Risk Voluntary Stewardship Practices for Guidance for Restoration Activities. Stewardship Centre for British Columbia. 2013.
- A Guide to Multi-species Restoration on the South Coast. Kym Welstead. 2012
- A Guide to Community-Based Compensatory Fish Habitat Monitoring. Pacific Salmon Foundation & Adamah Consultants. 2010.
- Are forested buffers an effective conservation strategy for riparian fauna? An assessment using meta-analysis. Laurie B. Marczak et al. 2010.
- Do riparian zones qualify as critical habitat for endangered freshwater fishes? John S. Richardson et al. 2010.
- Riparian vegetation: degradation, alien plant invasions, and restoration prospects. David M. Richardson et al. 2007.
- Conservation Thresholds for Land Use Planners. Environmental Law Institute. 2003.

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Habitat restoration projects can be complex. This guide is not a substitute for the expertise of experienced professionals and practitioners. For assistance, consult professional organizations like the College of Applied Biology.⁴

1.3 Defining the target/What is a stream community?

Streams are watercourses with defined banks and a scoured bottom (streambed) composed of mineral soils of various composition and size which has been deposited by flowing water. Water may flow on a permanent or intermittent basis. In developed areas, features constructed to divert or manage runoff and high flows (e.g. ditches, diversion channels) may support stream characteristics and can provide valuable habitat for fish and wildlife.

The riparian area or zone refers to the vegetated transitional interface between a water body (lake, stream, wetland, ocean) and upland habitats. While the boundary of this transition zone may be hard to define it can be as narrow as a few metres (e.g. ditches, headwater seepages) and as wide as hundreds of metres (large river systems and floodplains). These areas provide a buffer, typically vegetated with a diverse plant community that protects water quality by intercepting and filtering surface runoff from adjacent or upland areas. By slowing down or attenuating runoff riparian areas also provide a valuable service in slowing and dispersing flood waters. As complex ecological communities these natural services are often prone to disturbance and impacted by human activities.

1.4 Why are streams and riparian areas important?

British Columbia's South Coast has an abundance of watercourses. Before European settlement, First Nations relied on many of these rivers and streams as a primary source of food. Today, the Fraser River is still the most productive salmon producing river in the world. A sum of its tributary parts, this internationally recognized watershed could not maintain its productivity without the thousands of small streams that feed into it. Beyond their fisheries values, streams act as a life-giving arterial network of water for a host of aquatic and terrestrial species.



Mission Creek, North Vancouver. Photo: DHC.

⁴ <https://www.cab-bc.org>. Members of the College of Applied Biology are professionals who meet high standards for entry into the College and the right to the designation, RPBio, Registered Professional Biologist or Registered Biology Technologist, RBTech. They are the practitioners who take the theoretical knowledge of biology and apply it in a wide variety of fields to help us manage and protect our natural resources to the benefit of the public.

OVERVIEW

Some of the South Coast region's most at risk species depend on streams and riparian communities for all or part of their life history. Besides salmon, species like the endangered Salish Sucker (*Catostomus sp.*⁴) and Nooksack Dace (*Rhinichthys cataractae* - Chehalis lineage)⁵ inhabit South Coast streams and are found nowhere else in Canada. The iconic Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*) a provincial species of conservation concern and favourite of recreational anglers utilizes tiny headwater systems as well as lowland rivers. The Fraser River and some of its larger tributaries are home to one of the world's most ancient fish species the endangered White Sturgeon (*Acipenser transmontanus* pop. 4). At risk aquatic specialists whose life history depends on healthy streams and riparian forests include Pacific Water Shrew (*Sorex bendirii*) and the Mountain Beaver (*Aplodontia olympica*) the most primitive rodent in the world cannot live far from streams and rivers. Another unique species, Coastal Tailed Frog (*Ascaphus truei*) requires cold, unpolluted streams and rivers and intact riparian forests. Tailed frog tadpoles spend almost seven years attached to rocks and boulders on the streambed before metamorphosing into adults who spend their life between instream and riparian forest communities.

Restored Streams and Riparian Areas Benefit Wildlife and People

- **Biodiversity:** Streams and riparian areas provide important and unique habitat supporting a diversity of organisms including fish, mammals, birds, amphibians, reptiles and invertebrates. Riparian vegetation provides shade and cover, and is a source of nutrients, organic matter, leaf litter, and downed wood.
- **Flood reduction:** Streams and riparian vegetation can convey, absorb and store surplus water and reduce flood impacts.
- **Water quality:** Riparian vegetation acts as a buffer to intercept rainwater, slow down and reduce surface runoff, trap sediment, and help filter out contaminants that may be contained in surface water before it can enter a stream. Vegetation, especially the interconnected root mass of riparian vegetation that hides below the surface helps stabilize banks and shorelines.
- **Natural conduit:** Streams and riparian areas function like an ecosystem's circulatory system, providing corridors for water, nutrients, wildlife, soils and debris to move and exchange through the landscape.
- **Human health:** Riparian buffers can help remove nutrients like nitrogen (contained in fertilizers, animal wastes, etc.) that might otherwise enter a watercourse or drinking water supply, which can pose health risks at high concentrations.
- **Quality of life:** Streams and riparian areas improve livability of urban areas and provide numerous opportunities for recreation including fishing, walking, and nature appreciation.^a

^a<http://www.epa.gov/ada/eco/riparian.html>.

⁵ Do riparian zones qualify as critical habitat for endangered freshwater fishes. Richardson et al. 2010. Can. J. Fish. Aquat. Sci. 67: 1197–1204.

OVERVIEW

WHY ARE STREAMS AND RIPARIAN AREAS IMPORTANT TO US?

1. recreation
2. aquatic wildlife habitat
3. terrestrial wildlife habitat
4. water storage
5. water quality: filtration

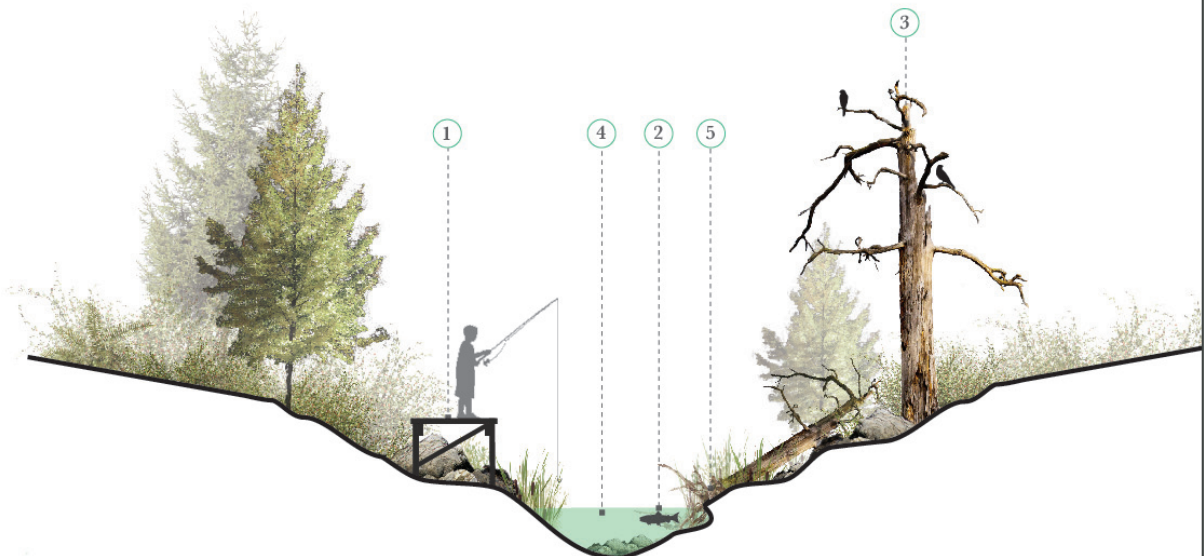


Figure 2. Why are streams and riparian areas important?

OVERVIEW

1.5 Threats and opportunities | What's at stake?

Urbanization, industrial and agricultural activity has resulted in the loss and degradation of many of our watercourses and riparian areas over time. This has affected the health and productivity of many of these ecosystems. Since the early 1900s, over 100 streams have been physically lost (i.e. buried, culverted) in the Lower Fraser Valley.⁶

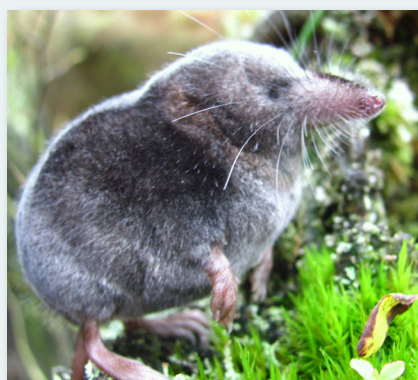
Many others are now considered threatened or endangered due to human impacts, including:

- Channelization and/or conversion of streams into stormwater systems below ground or in constructed ditches;
- Clearing of riparian vegetation for urban development;
- Flood control measures in low-lying coastal areas causing the loss of important intertidal estuary areas where rivers meet the ocean;
- Flood control measures that isolate rivers from natural floodplains and tributaries; and
- Pollution of waterways from sedimentation and toxic substances.

When streams and riparian areas become degraded, we not only lose habitat, but we also lose the ecological services they provide (e.g. clean water, flood mitigation, food production, recreation, etc.). For these reasons, restoration of degraded streams and riparian areas is an important objective.

Species Profile: Pacific Water Shrew (*Sorex bendirii*)

The Pacific Water Shrew is a federally listed endangered species considered especially susceptible to extirpation (i.e. local extinction). Adapted to a semi-aquatic lifestyle, the Pacific Water Shrew is usually found in riparian habitats associated with low-elevation streams and wetlands. It preys on freshwater invertebrates (insects, worms, snails), small fish and amphibian larvae. Urban development has degraded much of the preferred upland and aquatic habitat for this species. Stream and riparian restoration activities in areas of the South Coast where this species potentially occur should consider and include habitat features for this species. Features preferred by the Pacific Water Shrew such as intact riparian buffers with an abundant understory of dense shrubs, herbaceous plants and downed wood are the same characteristics that attract other species such as amphibians and birds.



Pacific Water Shrew. Photo: Denis Knopp.

⁶ Fisheries and Oceans Canada. 1998. Wild, Threatened, Endangered and Lost Streams of the Lower Fraser Valley: Summary Report. <http://www.dfo-mpo.gc.ca/library/229864.pdf>.

OVERVIEW

Species Profile: Coastal Tailed Frog (Ascaphus truei)

The Coastal Tailed Frog (also known as the Pacific Tailed Frog) is federally listed species of special concern that inhabits cool, fast moving streams. A member of the family Ascaphidae (“tailed frogs”), the genus is represented by only two species, Pacific (known as “Coastal”) and Rocky Mountain Tailed Frog, both found only in western North America. Tailed Frogs do not have an actual tail, rather males possess a fleshy appendage that is an extension of the cloaca (exterior opening that serves both intestinal and reproductive tracts in some species). Tailed Frogs are also the only North American frog to fertilize eggs internally. These frogs lay eggs on the substrate of fast flowing streams and tadpoles develop in these challenging environments.^a Recent studies on BC’s Central Coast have found that these amazing animals have unique migratory behaviours during breeding season and den communally in forests adjacent to their stream environments.^b Forest harvesting and urban development continues to impact many of the watersheds they occur in.



Coastal Tailed Frog. Adult and tadpole. Photos: M. G. Starkey and Brian Klinkenberg.

^aDevelop with Care 2014. Fact Sheet 17 - Tailed Frog.

^bMelissa Todd, Ministry of Forests Lands and Natural Resource Operations. 2014. Personal communication.

2. GOALS

A Multi-species Approach to Stream and Riparian Restoration



Pacific Water Shrew - Illustration by Carrielynn Victor

2.1 Supporting a diversity of species

When restoring habitat, it is important to recognize that important features and ecological functions may be missing or deficient. Low suitability habitat may support endangered species but often lack critical features, preventing species from meeting all their life history needs over the long-term. By understanding the complex linkages that are needed to maintain ecosystem health we can take a holistic approach that benefits multiple species across the entire landscape.

Applying this multi-species principle, restoration projects should consider:

- **Size:** Larger, contiguous (i.e. non-fragmented) areas can support a greater number of species and larger populations.
- **Quality:** Habitat degradation and disturbance resulting from development, pollution, invasive species, noise, light, free-ranging domestic pets etc. reduces habitat suitability for a diversity of species. Tolerance of human disturbance varies; some species, especially invasive or naturalized species, adapt to human environments quite well whereas others, like many of the most threatened species, avoid it.⁷
- **Diversity:** A diversity of habitat types and features are required to support multiple species. The four basic requirements to support any species are food, water, shelter, and space. Introducing greater diversity and complexity of habitat features will support a greater variety of plants and wildlife.
- **Connectivity:** Habitat that is connected to other nearby natural areas allows wildlife and plants to move, forage and promotes genetic dispersal.
- **Competition:** Some species may compete with each other for limited resources (e.g. food, nesting sites, etc.) or specific niches (e.g. aquatic habitat). Removal or addition of new predators or prey species through intended management or unforeseen introductions can have cascading effects on local populations. Careful consideration of inter-species dynamics is required as part of restoration approaches.
- **Disturbance:** Stream and riparian habitats experience periodic floods, wind throw and constant erosion, scour and sedimentation. They are among the most dynamic habitats on the landscape.

⁷The terms “urban adapters” and “urban avoiders” serve to categorize bird and animal species according to their ability to survive and even thrive in urban environments. McKinney, Michael. L. “Urbanization, Biodiversity, and Conservation.” *BioScience* 45:10 (October 2002): 883-890.

GOALS

Well- designed projects harness the stream’s own power to create and renew habitats while being be resilient enough to weather long-term effects such as climate change. Conversely, failure to account for these processes in design may lead to major project failures, risk damage to downstream areas and increase liability.

- Natural Succession: Habitats change over time as vegetation matures, beavers fell trees and new species colonize the site and natural disturbances alter the relative amounts of different habitat types.

Streams and riparian areas are a sum of their parts. There are a variety of micro-organisms, invertebrates, amphibians, fish, and other wildlife that rely on stream and riparian habitat. Simply put, habitat availability (and quality) determines what species are or could be present. Even the harshest stream environments support organisms adapted to those conditions and even our most degraded urban streams and agricultural ditches have the potential to create valuable habitat.



LSCR Filtration Plant Stream Restoration. Photo: DHC.

2.2 Harnessing nature’s healing ability

Healthy, functional ecosystems are the result of complex interactions between living (plants, fish, wildlife, and other organisms) and non-living (climate, soil, water, topography) components. The non-living components provide the foundation on which the living components will develop. Restoring these base conditions can be particularly challenging for stream communities which are highly sensitive to changes in water flow and water quality. Without the right soil and water conditions, the plants and animals that we want to inhabit these areas will not thrive.

Restoration plans should recognize that ecosystems take time to develop and evolve. Plans that follow the principles of natural succession take advantage of the recovery processes that have evolved in living systems.

This approach recognizes the power of working with nature and uses a more strategic approach to:

- Permit natural (recovery) processes to occur where desirable;
- Manage human disturbance if necessary to achieve desired successional pathways;
- Leverage resources to actively support/complement/accelerate these natural processes; and
- Re-establish natural flow and floodplain dynamics. These will interact with upland successional processes to establish and maintain a diverse, functioning stream community.

GOALS

Because restoration projects usually target degraded habitats that have had some sort of disturbance (whether natural or human-caused), this strategy can be particularly effective in re-establishing healthy ecological communities. By taking a holistic approach to restoration, limited resources in land and capital can be employed that benefit numerous species and restore more resilient, functional ecosystems.

The process of natural succession typically applies to terrestrial plant communities. However instream habitat can also change naturally over time. Special consideration should be given to the dynamic force of water. Water flow acts on the streambed and its banks to erode substrate, while at the same time transporting and depositing material from upstream. This continual force creates instream habitat that supports a diversity of life. A healthy stream community supports this process to evolve over time.

Species Profile: Western Screech Owl (Megascops kennicottii kennicottii)

The Western Screech Owl is a small cavity nesting arboreal (forest) dependent species found in close association with mature deciduous and coniferous stands, often in proximity to streams or wetlands. A member of the family Strigidae ("typical owls"), screech owls are masters of arboreal camouflage, the white to pale-grey plumage is streaked with black and brown making it difficult to see against tree trunks or cavities where it generally roosts and nests. The coastal subspecies tends to have greater brown colouration while the interior subspecies is greyer. This species is highly dependent on the availability of cavities and large diameter wildlife trees as well as stand densities typical of mature forests to provide camouflage from predators and prey. In the last 20 years the coastal subspecies has declined precipitously due to habitat fragmentation, loss of preferred mature nesting tree species and predation and competition from the Barred Owl (*Strix varia*).

Western Screech Owl. Photo above: Adult in Cheam wetlands Fraser Valley by Gord Gadsden. Photo below: fledgling or "owlet" by Camera Trap Codger.



3 STRATEGIES + PROCESS

What to Consider When Preparing a Stream and Riparian Restoration Plan?



Oregon Spotted Frog - Illustration by Carrielynn Victor

“Diversity by Design” describes the different phases of restoration, from developing an initial concept through to post-construction monitoring. These steps should be followed to ensure your project proceeds with the greatest chance of success. Although each stream and riparian community restoration project will differ, the steps and considerations will be broadly similar:

1. **UNDERTSANDING THE SYSTEMS:** Develop an inventory of living and non-living components;
2. **MINIMIZE IMPACTS:** Plan for managing disturbance and stressors;
3. **SECURE THE BUILDING BLOCKS:** Restore the foundation for healthy ecosystem function;
4. **REPAIR THE FABRIC:** Establish stream and riparian communities;
5. **INCLUDE HABITAT FEATURES:** Provide species specific habitat features; and
6. **MONITOR AND MEASURE:** Adapt to challenges and evaluate success.

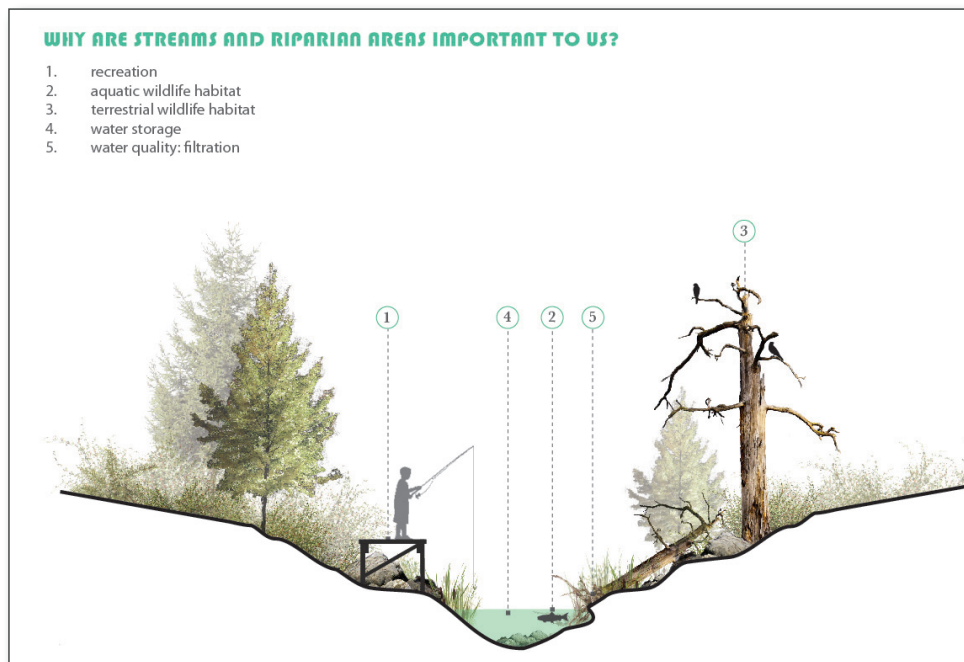


Figure 3. Components of a healthy stream and riparian ecosystem.

STRATEGIES + PROCESS

3.1 UNDERSTANDING THE SYSTEMS: Develop an inventory of living and non-living components

Existing characteristics (physical, biological, and social) of your restoration site should be fully understood to inform development of the restoration plan. The assessment should also include areas next to the site to help determine potential impacts.

Table 1. Understanding the site – Examples of physical, biological and social components and interactions for stream and riparian communities.

Physical	Biological	Social
<ul style="list-style-type: none"> • Water flow • Stream width, depth, channel substrate • Water chemistry • Instream habitat features • Riparian soils (nutrients, texture, compaction, organic content) 	<ul style="list-style-type: none"> • Tree species, size and stand structure • Tree and plant health (disease, pests, abiotic damage) • Terrestrial and aquatic vegetation • Endangered/rare plants • Invasive plants/animals • Fish, Wildlife, invertebrates 	<ul style="list-style-type: none"> • Neighbouring land use (development, roads, etc.) • Recreation use • Pets • Pollution • Vandalism • Stormwater or agricultural inputs • Wildlife and hazard trees management (downed wood and wildlife tree removal)

3.2 MINIMIZE IMPACTS: Plan for managing disturbance and stressors

An important step in the restoration process is managing disturbance. By removing the agent(s) that are causing degradation, recovery can begin and natural processes can start to function properly.

3.2.1 Invasive plants

One of the major threats to biodiversity, and one of the primary reasons restoration projects fail, is the presence of invasive plants. Many non-native or introduced plants can establish and out-compete native plant species. Invasive plants of greatest concern have fast growth rates and are able to reproduce and spread quickly.⁸

Problem invasive plants commonly encountered in riparian areas include Himalayan Blackberry (*Rubus armeniacus*), knotweed species (*Polygonum ssp.*), Lamium (*Lamiastrum galeobdolon*), Policeman's Helmet (*Myriophyllum spicatum*), and English Ivy (*Hedera helix*).

⁸ Zevit, Pamela. 2009. Battling the Alien Invasion: An overview of invasive plant species impacts in the Georgia Basin. <http://ibis.geog.ubc.ca/biodiversity/BiodiversityandInvasiveSpecies.html>.

STRATEGIES + PROCESS

Problem Invasive Species

Rock Snot or Didymo (*Didymosphenia germinata*) is a freshwater algae that forms massive blooms that smother the streambed and significantly impact stream communities. The algae is readily spread and can be very difficult to eradicate once established in a waterbody.

When it comes to riparian areas, one of the most threatening invasive plant species is Knotweed. This plant grows prolifically and is very difficult to eradicate without the use of chemicals. It spreads quickly and out-competes most other plants. It creates a dense monoculture which can destabilize stream banks causing erosion and sedimentation into streams. Knotweed (*Polygonum sp.*) is also allelopathic, a characteristic which allows it to alter soil chemistry to promote its growth while inhibiting the growth of other plant species. It is also highly effective at colonizing new sites. The plant will easily break apart, allowing segments to flow downstream and root in new areas. Treatment of this species is a priority on the South Coast. Knotweed is best treated with stem injection using glyphosate; however Knotweed may be starting to demonstrate glyphosate resistance and restrictions apply when applying pesticides in close proximity to water bodies.^a



Stem injection control in Knotweed thicket. Photo: USDA Forest Service/Jennifer Grenz ISCMV.



Reed Canarygrass infilling a creek channel that was part of a restoration project in Coquitlam, BC. Photo: Pamela Zevit.

Reed Canarygrass (*Phalaris arundinacea*) is prolific in agricultural ditches and floodplain areas. This species is very dense and is able to outcompete most of our native shrubs. Fortunately Reed Canarygrass is intolerant of shady conditions. Planting large stock pioneer tree species can overtop and shade out Canarygrass over time. Black Cottonwood and Red Alder are particularly effective. These trees must be planted at a high density and the understory brushed out for the first several years of growth. Hardhack (*Spiraea douglasii*) and Snowberry (*Symphoricarpos sp.*) are shrubs that can establish quickly in disturbed conditions and can out-compete Reed Canarygrass.

^a Jennifer Grenz, pers. comm. 2015. <http://www.iscmv.ca/species-profiles/japanese-knotweed>.

STRATEGIES + PROCESS

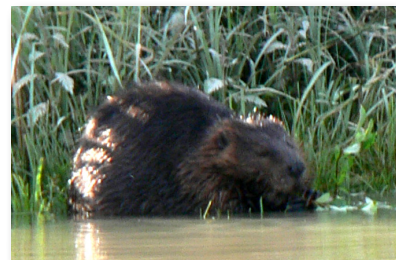
Treatment of invasive plants must occur before the beginning of the project and continue over subsequent years until the native plant community is well established. Sometimes this can be a decade's long commitment. Treating invasive plants in the early years of a restoration project is a good return on investment, allowing native plants to establish with minimal competition. Treatment can be chemical, mechanical, or biological. The best treatment option will depend on a number of factors: target species being treated, cost, area infected, site conditions, and safety. Chemical treatment has specific regulatory requirements pertaining to water quality that must be considered. In addition to requiring a qualified professional and appropriate permitting, local government bodies and invasive species councils should be consulted prior to beginning any work.

Treatment timing varies depending on the target species. It is best to avoid treatment once seeds or fruit appears to avoid further spread. Proper disposal will help reduce risk of spread elsewhere.

Consulting with regional invasive species committees is an important step to ensuring the appropriate bases are covered in project planning. Visit the Invasive Species Council of BC (ISCBC) website to connect with the regional invasive species council in your area and to find out more information on species-specific management practices.⁹

3.2.2 Invasive Fauna

Beavers are a native species that can be difficult to manage. Although they are directly responsible for creating valuable aquatic habitat, their activity in urban and rural watersheds can affect hydrology, drainage and vegetation. In some circumstances, their activities can pose a risk to buildings, infrastructure, farmland and people. Trees and shrubs in riparian areas are often targeted by beavers, which is a concern for restoration efforts. Although beavers have a preference for deciduous trees, they will target all species both large and small as well as smaller shrub species. Beavers are also known to damage domestic blueberry plants on farms in the Fraser Valley. Trees and shrubs can be protected from beavers by installing fencing around groups of trees or individually around their base. Fencing must be installed such that it prevents beavers from burrowing underneath into excluded areas or pushing the guards up allowing access to individual stems.¹⁰ Beavers can also benefit habitat restoration. The US Fish & Wildlife Service released a series on “Working with Beaver to Restore Streams, Wetlands, and Floodplains”.¹¹



Beaver. Photo: Isabelle Houde.

There are some species of introduced fish which are very difficult to eradicate once they have become established. Non-native carp, bass and catfish species are widespread in South Coast waterways. Even native fish species such as trout and char can be an issue, if introduced or transplanted into stream communities

⁹ Invasive Species Council of BC (ISCBC) (<http://bcinvasives.ca>). On the South Coast four invasive species councils operate: the Invasive Species Council of Metro Vancouver, Sea to Sky Invasive Species Council, Fraser Valley Invasive Plant Committee and the Coastal Invasives Species Council.

¹⁰ <http://www.beaversww.org/solving-problems/trees-and-plantings>.

¹¹ The Beaver Restoration Guidebook. Working with Beaver to Restore Streams, Wetlands, and Floodplains. <http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/BeaverWorkshops.asp>.

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where they are not native or historically found. As with exotic species, they can spread quickly through a watershed, often feeding on endemic fish and amphibian species. Actions must be taken early on as other than complete treatment of a waterway with pesticides, these species are impossible to eradicate once they have become established. Monitoring and early response, or as is more typical, ongoing control and management is a necessary investment to maintain the health of native species in streams on the South Coast.

3.2.3 Hydrology and drainage impacts

Drainage control and flood protection structures such as dykes, floodgates, pump stations and dams have had significant implications for aquatic species on the South Coast. These structures can prevent natural upstream and downstream migration and alter stream hydrology.¹¹ Roads, ditches and other infrastructure can also affect water level and flow in streams. In urban areas, stormwater systems prevent natural infiltration and can cause rapid fluctuation in water levels and flow. Most stormwater systems drain in to natural waterbodies. The influence of these features should be carefully investigated to determine their impacts and to identify opportunities to improve stream and riparian function. Installation of fish and wildlife-friendly passage designs should be encouraged over traditional infrastructure where appropriate.

Stewardship Practices

The Stewardship Centre for BC has recently published resources to help manage drainages on agricultural lands and protect species at risk. These include Drainage Maintenance in Agricultural Waterways, Stewardship Practices for Riparian Areas in Settled Landscapes, and Guidance for Restoration Activities in Riparian Areas. The SCCP has current drainage maintenance best practices being employed on the South Coast by municipal and provincial land use authorities on its website sccp.ca via the Guidelines and Resources tabs.

3.2.4 Contaminants and nutrient loading

Many streams are located in agricultural or urban areas and can become receiving environments for pesticides, fertilizers, effluent, manure, hydrocarbons, chemicals and other substances introduced through stormwater runoff, groundwater, and/or overland flow. Increased amounts of nitrates and phosphates from livestock manure or lawn and garden maintenance can cause algal blooms which deplete oxygen from aquatic ecosystems and can harm fish and other aquatic organisms.

3.2.5 Soil disturbance

Ground compaction can prevent water from infiltrating soil. This can increase water runoff, limit plant and tree root growth, and can affect burrowing animals. In agricultural areas, compaction can be mitigated for by tillage or using machinery that reduces compaction (e.g. over-size tires). On commercial and industrial sites, soil compaction is often a requirement, which can be a concern for adjacent natural areas. Maintaining intact riparian habitat around streams provides a buffer to collect and filter overland flow.

¹¹ http://www.thinksalmon.com/reports/FBC_Environmental_Protection_in_Flood_low_res.pdf.

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Fish and Amphibians in Ditches?!

Many ditches are actually channelized natural streams, but even ditches constructed to manage water flow around urban and agricultural land uses provide important fish and amphibian habitat. Although they generally lack a diversity of habitat features and structure; they do provide habitat that can be used by some fish species. For example, Cutthroat Trout (*Oncorhynchus clarkii clarkii*) and Coho Salmon (*Oncorhynchus kisutch*) may overwinter in constructed ditches that are completely dry for most of the summer. Oregon Spotted Frog (*Rana pretiosa*) are known to utilize agricultural ditches and drainage channels.^a There are opportunities to enhance habitat quality through bank stabilization and riparian planting, and improved ditch maintenance practices.^b

Many channelized drainages like this one along Highway 1 in Coquitlam are actually the remnants of stream channels. Often they support a high diversity of aquatic life including salmonids especially if sustained by groundwater inputs. They also provide nesting and overwintering habitat for songbirds, waterfowl and stepping stones of cover for other wildlife seeking refuge in fragmented landscapes.



Highway 1, ditched watercourse. Photo: Pamela Zevit.

^a Recovery Strategy for the Oregon Spotted Frog (*Rana pretiosa*) in Canada. 2014.

http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=975.

^b Species at Risk Voluntary Stewardship Practices for: Drainage Maintenance in Agricultural Waterways. 2013.

http://stewardshipcentrebc.ca/PDF_docs/sar/StewardshipPracticesforDrainageMaintenancePilot12-2013.pdf.

Best Management Practices for Drainage Maintenance Works in Oregon Spotted Frog Habitat. Draft 2010.

<http://sccp.ca/guidelines/best-management-practices-drainage-maintenance-works-oregon-spotted-frog-habitat>.

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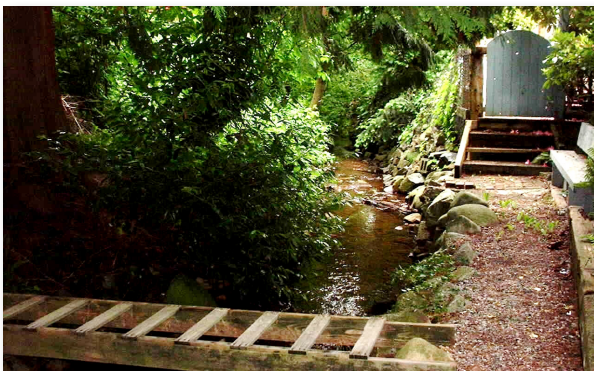
3.2.6 Sedimentation

Soil erosion can cause increased sedimentation in streams. Small sediment plumes are often quickly diluted to levels that will not influence aquatic species. Large sediment events can negatively impact aquatic species and deposit fine sediments, changing the nature of channel substrates. This is particularly a concern in stream reaches with spawning gravels.

3.2.7 Recreational and encroachment impacts

Unwanted human access to stream and riparian communities as well as restoration sites can have detrimental impacts. Development which takes place in or around stream communities can result in clearing and reduction of riparian vegetation. Development that occurs in close proximity to the riparian zone edge can generate significant “adjacency or edge effects”. These can range from weakened tree root systems (from soil disturbance or root damage), light and noise pollution and increased risk for windthrow and wildfire.

New development, roads and other infrastructure can affect water levels in soils. Homeowners may employ inappropriate pruning or cutting practices further damaging edge trees. Trees weakened by these cumulative effects can become structurally unstable or susceptible to disease leading to further tree removal. Other risks associated with urban development include building of unauthorized trails, increased stress and predation by domestic pets on local wildlife and the establishment and spread of invasive plants. Off-trail usage (e.g. mountain bikes, off road vehicles) damages soils and vegetation and disturbs wildlife. Free-ranging domestic pets (e.g. off-leash dogs), can have negative impacts to riparian and aquatic plant communities and disturb wildlife.¹² Mitigation strategies include education and awareness (e.g. signage), construction of natural or artificial barriers, or alternative siting for trails and/or roads.



Backyard encroachment. (left) Streambank modification into a headwater stream in Coquitlam (armouring of the streambank and removal of vegetation as well as stream crossing structure). A situation all too typical of many urban and rural streams. Photo: Pamela Zevit. (right) Removal of stream bank vegetation in outflow stream on the Sunshine Coast. Photo: Isabelle Houde.

¹² Impact of Dogs in Parks <http://www.metrovancouver.org/dogs/Pages/ImpactofDogsinParks.aspx>.

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3.3 SECURE THE BUILDING BLOCKS: Restore the foundation for healthy ecosystem function

Water, soil and topography provide the foundation of functioning stream and riparian ecosystems. The challenge for most stream and riparian restoration projects is ensuring that functional habitat can be maintained in a highly dynamic ecosystem. Water flow and quality is highly dependent on conditions in the surrounding watershed; sometimes restoration efforts at the site level can be negated by upstream influences (e.g. high energy flash flooding from stormwater runoff).

3.3.1 Water

Water quality is a significant factor affecting the health of aquatic ecosystems. Water availability is critical to the development of riparian communities and determines the dominance of specific plant species. Water quality is affected by numerous factors, many of which may originate upstream or off-site. Sediments, contaminants and other inputs can enter a watercourse many kilometres away. These inputs are often introduced through direct discharge, runoff, or overland flow. Urban and farm environments are particularly challenging and make pinpointing the source of contaminants difficult.

Considerations for controlling water quality:

- Water source: In many urban areas, contributing flows enter the stream through the stormwater system. This can cause rapid changes in volume and velocity during storm events. It is important to understand where water is coming from whether it is a natural watershed or an urban stormwater system.
- Nutrient loading and contaminants: In urban and agricultural areas, there are many sources of contaminants that can enter a stream system. In urban environments use of cosmetic pesticides has become an issue as it has been found that concentrations increase with urbanization.¹³ Pesticides have also been found to interfere salmon olfactory systems (ability to smell) which can severely impact their ability to navigate or avoid predators.¹⁴ As well stormwater runoff has been tied to unusual episodes of pre-spawning mortality in salmonids.¹⁵
- Sedimentation: Suspended fine particles directly affect the ability of fish to breathe and can reduce visibility, impeding their ability to find food. Settling sediments can also cause extensive damage to spawning areas or impact invertebrate communities and aquatic foodchains by clogging the pore space between gravels. Sediments also bind to heavy metals and other contaminants and increase their transport and exposure to plants, fish and wildlife that use the aquatic community.¹⁶

¹³ Pyrethroid Insecticide Contamination of Streams Increases with Urbanization. http://toxics.usgs.gov/highlights/pyrethroids_in_streams.html.

¹⁴ Real-world pesticide mixtures harm salmon. <http://pubs.acs.org/doi/abs/10.1021/es087162w>.

¹⁵ Landscape Ecotoxicology of Coho Salmon Spawner Mortality in Urban Streams. <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0023424>.

¹⁶ Impacts of Sediment to Aquatic Habitats. City of Abbotsford. <http://www.abbotsford.ca/Assets/2014+Abbotsford/Planning+and+Development/Planning/Environment/Impacts+of+Sediment+to+Aquatic+Habitats.pdf>.

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- Temperature: Direct exposure to sunlight can raise water temperature. This can be beneficial or detrimental depending on the stream. Temperature directly influences oxygen levels in the water.
- Acidity: The pH of a healthy stream is generally stable and is an indicator of contaminants. Many aquatic species are highly susceptible to changes in acidity.

3.3.2 Soil

Soil is an essential growing medium for plants. Soil quality refers to the soil's capacity to perform important services including nutrient cycling, water regulation and filtration, and to support plants, animals, and microorganisms. Factors affecting soil quality (and function) include texture, coarse fragment content, compaction, salinity, pH, organic matter and soil life (e.g. micro-organisms, invertebrates, etc.).

Substrate: The substrate is the underlying material on which plants, or other organisms such as algae, will grow. Riparian areas are usually associated with a deeper soil substrate, which is derived of both mineral and organic material. This material is nutrient rich and will permit a wide variety of plants to grow and thrive.

The substrate in stream and riparian areas is highly influenced by local geology, water and channel dynamics. Soil along the bank edges is frequently saturated by water, and has lower oxygen and nutrient availability. Bank erosion caused by fast moving water can expose soils along stream banks and prevent revegetation. Sediment deposition in slower moving water can create new substrates (e.g. sand/gravel bars) for plants to colonize. Stream substrates are scoured by water. Generally, the higher the stream flow and gradient, the greater the size of particles that remain. High velocity streams and those with steeper gradients will have a higher component of gravels and cobbles. Low flow streams can have finer textured substrates including silt, clay and organic matter. Streambed conditions can be modified to meet specific objectives (e.g. spawning



Stream substrates vary significantly dependent on flow velocity, gradient and type of parent materials (geology) of the surrounding watershed. (left) High velocity steep gradient stream with large boulders and cobbles. (right) Low velocity floodplain stream with nearly zero gradient and substrate of fines, small gravels and organic materials. Photo: Pamela Zevit.

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Erosion and sediment control tips:

Exposed soil in riparian areas can result in increased surface erosion and sedimentation, which can affect water quality. Erosion control and slope stabilization techniques should be implemented until vegetation is well established. Gentle gradients will reduce the risk of erosion and are also more wildlife friendly (steep slopes and vertical drops can impede wildlife movement). Cross slope benches and placement of large stems of wood also help to prevent the impacts of surface runoff. Surface erosion can be controlled by applying temporary surface covers such as straw or fabricated erosion control fabrics (e.g. biodegradable matting). These will add organic matter to the soil, retain moisture and aid in plant germination. Prompt seeding with a native grass and legume mix (e.g. clovers) is also a good idea to quickly stabilize disturbed riparian area.⁹ The diversity of ground cover will also benefit wildlife such as voles, Muskrat and native wild pollinators. These mixes germinate well even in cool fall conditions, provide good cover for plantings in the first year (as well as natural nitrogen fixing) and are outcompeted and gone from the site within two years as plantings mature.



ESC installed to protect a stream restoration project, Tynehead Park. Photo: DHC .

⁹It is critical to ensure that seed mixes are free of noxious weed seeds and do not utilize wildflower species that are not endemic to the area or grasses which can become invasive. As an example many wildflower mixes contain ornamental lupine species which can hybridize with the federally endangered streambank lupine (*Lupinus rivularis*) which is found in isolated populations in Metro Vancouver and southeast Vancouver Island.

habitat). Salmonids, for example, prefer streambeds composed of gravel and cobble, with low amount of sediments. Stream substrates also attract aquatic invertebrates which subsequently become food for fish, aquatic mammals like water shrews and specialist bird species like Harlequin Ducks and American Dippers.

Compaction: Disturbed soils can be highly compacted¹⁷, resulting in smaller pore spaces which can inhibit water infiltration, nutrient availability, and root growth. This is often the case where large machinery has been working near a stream bank. Some surface modification may be required to ensure soil is not overly compacted prior to planting. Ploughing or roughing is an easy way to ensure soil is not overly compacted prior to planting and will also reduce erosion and aid in moisture retention. Adding soil with a higher sand content will provide ample pore space for root growth and is less susceptible to erosion and sedimentation. Organic material can also be added to relieve compaction, encourage water infiltration, and allow roots to quickly develop to stabilize the soil.¹⁸

¹⁷ <http://soilweb.landfood.ubc.ca/labmodules/compaction>.

¹⁸ The Science and Practice of Sustainable Sites: Practical Implementation Soil Protection & Restoration.

http://depts.washington.edu/uwbgs/docs/sites/Sites_Soil_McDonald_Stenn_Berger.pdf. Soils for Salmon: <http://www.soilsforsalmon>.

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(left) Traditional practice of re-grading and tamping down or compacting a streambank prior to seeding and planting. (right) Employing soil roughening to mimic natural surface soil horizon characteristics, improving soil moisture retention and planting environment. Photos: Pamela Zevit.

Willow is the Answer!

Restoration efforts in riparian areas should focus on re-establishing healthy soils and supporting fast growing plants and trees that will stabilize channel banks. In areas with enough sunlight, willow is an excellent species for restoring riparian habitat. It grows quickly and is tolerant of water saturated soil. It is also very resilient and will often survive bank wash outs. More elaborate ‘bioengineered’ structures built from willow can be used to stabilize more erosion-prone areas.



Restoration site in Coquitlam: Year 1, hydro-seeding bank with grass and legume mix and livestaking floodplain with willow, bank planted with alder and cottonwood seedlings. All plantings salvaged from nearby vacant lot. Photo: Pamela Zevit.



Year 3. Photo: Pamela Zevit.

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Got shade and steep banks?

Then consider species such as Salmonberry (*Rubus spectabilis*), Beaked Hazelnut (*Corylus cornuta*), Vine Maple (*Acer circinatum*), Dull Oregon Grape (*Mahonia nervosa*), Salal (*Gaultheria shallon*) and Sword Fern (*Polystichum* sp.). These species, especially Salmonberry, Vine Maple and Sword Fern do well in the shade, will tolerate variable soil moisture conditions and provide a structurally diverse understory with deep, soil-binding root systems. They also spread easily once established. As well the root masses of understory plants like sword fern are utilized by a number of forest dependent species such as the terrestrial Red-backed Salamander (*Plethodon vehiculum*).



Ravine site in Coquitlam. Steep banks subject to encroachment and erosion with or without dense tree canopies are often hard to replant due to access and safety issues. As well many of the preferred erosion control species are sun loving. However native species such as Vine Maple and Sword Fern are well adapted to these constrained conditions and provide excellent root mass soil binding services while contributing to improved soil conditions and wildlife cover as slower growing overstory tree species take hold. Photos: Pamela Zevit.

Beware of Processed Topsoils

Processed topsoils or soil amenders are often used in restoration projects; however, they add challenges. These include higher project costs for purchase, transport, and placement; variable quality; and contamination with invasive plant seed and root fragments which can germinate on the site. Non-native and processed topsoil should only be considered where existing conditions are too poor to support pioneer plant communities.

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3.3.3 Topography: Channel Design

Channels can be designed or enhanced to provide a variety of habitats for both aquatic and terrestrial species. However, they should also meet other objectives including bank stabilization and stream grade control. Generally, there has been an evolution in channel design towards use of more natural substrates and meander patterns whenever possible. Restoration practitioners must also be aware that streams are highly variable ecosystems; water is a powerful force and change is inevitable. Natural events such as flooding, for example, can undo years of restoration work in a very brief time period. It is very important to understand the nature of water flow in a stream and to design features required to withstand them. In many cases consulting with a hydrologist or geomorphologist would be prudent to ensure the long term stability of the channel design. Many specialists in the private sector or staff who work with the provincial or federal governments are quite willing to provide a certain level of volunteer expertise to local community projects. Check professional associations such as the Association of Professional Engineers and Geoscientists (BC), BC Institute of Agrologists or College of Applied Biology of BC to find experts who may be near you. The following is a brief description of channel types and features that can be incorporated into restoration projects.

Stream Gradient and Fish Habitat

Streams are often classified as “fish-bearing” and “non-fish-bearing” as a means to distinguish those that support fish and those that do not. Fish-bearing streams are usually lower gradient watercourses (<20% average slope) that have flow all year. However, some seasonal streams provide important overwintering and rearing habitat. Isolated populations of fish, often resident species such as Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*) and Bull Trout (*Salvelinus confluentus*)—a type of char, can also be found in places typically not supporting other fish species (e.g. streams >20% gradient). During high flood events fish can be washed down into steeper sections of a watershed and manage to survive in a short reaches. Streams which are technically non-fish-bearing can still provide food (e.g. insects) and nutrient contributions to downstream habitat. Streams are a continuum and it is important to remember that every component from headwater to estuary plays a part in maintaining a healthy ecosystem.^a

^a Life Beyond Salmon Streams: Communities of Headwaters and Their Role in Drainage Networks. 2000. John Richardson. Head Forest Science and Conservation University of British Columbia.

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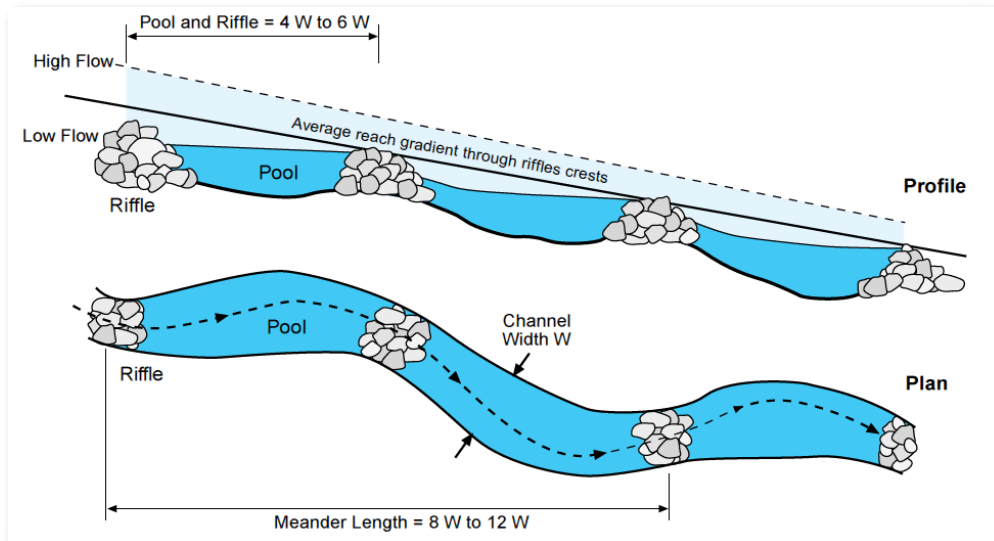


Figure 4. Pool riffle sequences. Figure from Streamline, Volume 7.

Habitat Variety in Streams

Stream habitat is influenced by a number of factors: streamflow (volume, velocity), water quality, gradient, depth, sinuosity, substrate (natural material on stream bottom), cover features, and riparian vegetation. Due to the seasonal nature of stream habitats, many of these factors can change markedly throughout the year. Habitat characteristics that generally support fish include: a healthy riparian plant community, stable stream banks, a diversity of channel features such as pools, glides, riffles, side channels and bends, and cover for fish such as undercut banks, large stems of wood, deep pools and boulders. Incorporating different instream habitat features benefits multiple species. Some endangered fish species such as the Salish Sucker (*Catostomus* sp. 4) prefer deeper ponds whereas the Nooksack Dace (*Rhinichthys cataractae* - Chehalis lineage) prefers faster moving, shallow water.^a

^a An Assessment of Potential Critical Habitat for Nooksack Dace (*Rhinichthys cataractae* ssp.) and Salish Sucker (*Catostomus* sp.). 2007.
http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2007/RES2007_058_e.pdf.

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Riffle-Pools: Riffle-pool complexes are perhaps the most common channel type that is re-created in restoration projects. They are typically found on low gradient streams (1-4%) that have a predominantly gravel substrate. Generally, riffle-pools follow a sequence that repeats at an interval equivalent to six channel widths in length, although this distance may decrease on higher gradient streams.¹⁹ On a meandering stream, the riffles occur on the straight while the pools are situated on the outside of bends. The distance between two outside banks on a meander should be between 8 and 12 times the full bank-width of channel. To create riffles, a trench should be excavated below the scour level and then filled with well graded material (cobbles and small boulders).

Step-Pools and Cascades: These channel type are associated with steeper stream gradients. Step pools typically occur between 4 and 10%, while cascade habitat types are between 10 and 30%. Large rocks can be placed in differing configurations and intervals to create small, short drops (e.g. steps). Rocks must be large enough to be stable in high flow. They are often placed at 'nick points', areas where the streambed is starting to be undercut or incised, to prevent further headcutting upstream. Steps must not be too high in channels where fish are present, to prevent impeding their movements.

Removing Fish Barriers

Human structures (dams, culverts) and natural barriers (waterfalls) can prevent the migration of fish species and isolate populations in certain reaches. Often, suitable stream habitat does not support a species simply because it is cut off from natural populations. Removing fish barriers is one of the most beneficial strategies for stream restoration. In urban areas, this often involves replacement of poorly designed culverts. Removal of natural barriers however must be assessed and undertaken with care. Often waterfalls and other natural barriers have created unique populations of fish species which have adapted and evolved in isolation from downstream influences (Steelhead Trout, Bull Trout, Coastal Cutthroat Trout and even Three-spine Stickleback are examples of this). As well many fishless headwater systems support unique assemblages of amphibians (Pacific Tailed Frog, various salamander and newt species). Introduction of fish, e.g. salmonids could severely impact and possibly even extirpate these unique communities.



Coho salmon trying to migrate upstream through a perched culvert. Photo: Meegan M. Reid KITSAP SUN.

¹⁹ Restoration of Riffle:Pool Sequences in Channelized Streams. Streamline, BC's Stream Restoration Bulletin.

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Side Channels: In urban areas, many floodplain and side channels that are naturally associated with larger streams have been removed or degraded. Creation of connected side channels provides valuable protective cover for rearing fish as well as refuge and foraging areas for species such as Pacific Water Shrew, great Blue Heron.



Reconstructed side channel in riparian area based on historic floodplain areas adjacent to the Coquitlam River. Photo: Pamela Zevit.

Instream Structures: A variety of features and structures can be integrated into the stream design to achieve multiple objectives (e.g. grade and bank stabilization, habitat enhancement). These structures are easily integrated into riffle-pool and step-pool sequences to help control water velocity and direction, and reduce downcutting (incision); however, care must be taken to avoid unwanted sedimentation, scour, and/or bank erosion.²⁰ Some of the more common structures include vanes and weirs:²¹

- **Rock Weirs:** A small rock dam designed to narrow and direct channel flow and create downstream scour pools. The weir is pointed downstream at an angle with large footer stones entrenched in the channel bed. Weir stones are placed behind the footer stones creating a weir that is usually just below the waterline.
- **Boulder Clusters:** A cluster of several large boulders is installed, sometimes in association with a rock weir, and usually mid channel to create scour pools and slackwater refuge areas.
- **J- hook Vane:** This structure is positioned on the outside of stream bends, and is constructed of logs, rocks, and root wads. The vane is angled upstream and is one third the bankfull width. The J portion is located in the centre third of the stream.

²⁰ http://www.polytechnic.edu.na/academics/schools/engine_infotech/civil/libraries/hydrology/docus/Weirs.pdf.

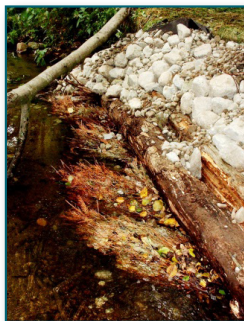
²¹ <http://www.wildlandhydrology.com/assets/cross-vane.pdf>.

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- V-log drop: Designed to direct flow to middle of the channel and create scour pools. Two logs (minimum 40 cm diameter) are placed with the V pointing upstream, with the lowest point at the stream invert. Large rocks and rebar can be used to stabilize the logs.
- Undercut banks: Overhanging banks provide secure cover habitat for fish. These often will naturally form under the roots of mature trees.
- Downed Wood: In a natural system, trees growing next to streams regularly fall over and create valuable instream habitat (logs and root wads). These features provide important cover and can influence hydrology, creating valuable pools and eddies for fish and other species utilizing stream environments to rest. Tree removal in riparian areas reduces regular input of debris into urban streams. Often this results in a need to artificially enhance wood recruitment. An excavator can be used to install large features. Logs should be secured to banks (buried or cables) to prevent unwanted downstream impacts. Smaller features can be installed by hand.



Log structures installed for enhancement of lower Lynn Creek, and Stumps placed in tributary of Serpentine River. Photos: DHC.



Examples of small hand installations to restore eroded banks and provide instream cover in a small stream in Coquitlam. Materials included Christmas trees, small rootwads, salvaged downed wood combined with variable bedload material. Upper portions of the installations were topped with amended soil and planted. Photos: Pamela Zevit.

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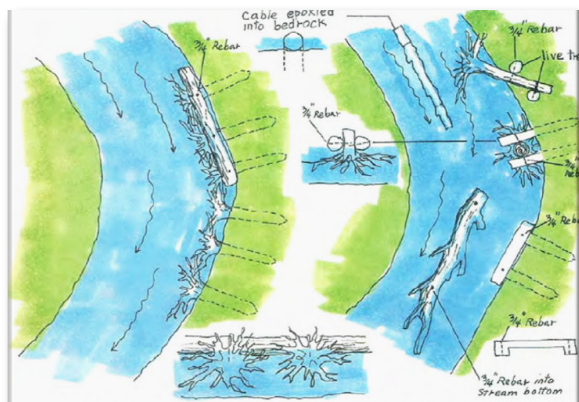
Bank protection: Bank erosion is a serious concern for restoration projects. Failing banks can result in loss of vegetation and increased sedimentation, leading to degraded habitat. Continued erosion may lead to creation of steep vertical banks, encouraging stream downcutting. Steep banks prohibit wildlife movement between the creek and riparian area.

Several bioengineering techniques have been developed to help stabilize and protect channel banks:

- **Geo-matting:** cocoa matting is installed on banks and live staked. Mats should be trenched in and secured at the toe.
- **Root wads:** Root wads should be placed on the outside bend of a meander, facing upstream. It is important not to place the root wad too high or too far out into the channel. A footer log (>50 cm in diameter) is used for support, and should be entrenched below the streambed. Root wads can be clustered together to improve stability; however, the ground in and around these structures should be compacted.²²
- **Brush mattress:** Brush mattresses are used to provide immediate protection of exposed and unstable stream banks. Live willow cuttings are commonly used (although other species may be suitable). Approximately 20-50 cuttings per metre are driven into a trench excavated at the toe of the bank. The cuttings are further secured by a stake and lattice network which keeps them in place. It is important to use this method during the dormant period, and in areas where there is sufficient native growth that it will not be negatively affected.²³



Installing Geo-matting. Photo: DHC.



Example of layout plan for cover logs and rootwads.

Islands: Creation of isolated islands in larger slow moving streams can provide secure habitat for many species. In particular, ground nesting birds that are more susceptible to predation or disturbance. Islands can be small but should be armoured to prevent erosion.

²² <http://www.aces.edu/waterquality/streams/Town%20Creek/presentations/construction/McLean%20Auburn%20Stream%20Powerpoint.pdf>.

²³ <http://www.urban creeks.org/Brush%20Mattress.pdf>.

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3.4 REPAIR THE FABRIC: Establish stream and riparian communities

There are two general approaches to restoring vegetation communities on a site. Passive restoration focuses on removing the disturbance agent(s) and providing a healthy growing environment that will allow nature to follow its own path. Generally, the soil is already fairly well developed and there is an existing native seed bank. However, natural regeneration can be a slow process and may not always achieve desired results. Invasive plants can establish soon after disturbance and out-compete native vegetation.

Active restoration involves more intensive management intervention, with the objective of kick-starting succession to establish a desired biological community. Restoration will often focus on the establishment of a young, early succession plant community. These include pioneer plants that are adapted to harsher growing conditions and establish quickly. Once these pioneer plants establish, other species can be introduced. Some maintenance (e.g. spacing, thinning) may be required to improve growing conditions for subsequent plantings.

3.4.1 Plant Selection

Plants selected for a restoration project should be adapted to the specific soil conditions associated with the site. Most terrestrial plants are unable to handle stress resulting from prolonged exposure to water; while aquatic and semi-aquatic plants are adapted to these conditions. A stream and riparian restoration plant prescription usually includes mostly terrestrial plants along the stream banks. Floodplains and associated wetland areas may be planted with aquatic species.

Although a diversity of plants is recommended, it is more important to select plants that can tolerate the site conditions, establish quickly, withstand competition, and provide ecological value. This often means prescribing a lower diversity of highly adaptable species. Examples of some of the more common riparian species that establish well on the South Coast include Red-osier Dogwood (*Cornus stolonifera*), Hardhack (*Spiraea douglasii* ssp. *douglasii*), Salmonberry (*Rubus spectabilis*), Pacific Ninebark (*Physocarpus capitatus*), willow species, Red Alder (*Alnus rubra*), Paper Birch (*Betula papyrifera*), Beaked Hazelnut (*Corylus cornuta*) and Black Cottonwood (*Populus trichocarpa*).

Stream and Riparian Facts: Some Plants Love Getting their Feet Wet, Others do Not

Plants in riparian areas grow within distinct bands differentiated based on their proximity to the water:^a

- Water-loving plants (e.g. sedges, rushes, willow, Red-osier Dogwood) with strong, deep roots that help stabilize banks.
- Water tolerant plants (e.g. Salmonberry, Black Twinberry, Hardhack, Black Cottonwood) that stabilize banks and slopes and allow other plants to establish. These woody plants are often the first to establish.
- Upland plants (e.g. Red Alder, Snowberry, Indian Plum, Hazelnut) that are fast growing but less tolerant of a high water table.

^a <http://ohioline.osu.edu/ls-fact/0001.html>.

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3.4.2 What size of plants is best?

Generally, greater success is achieved by using smaller stock that have a high root to shoot ratio. This means that there are lots of roots to support the above ground growth. It is also physically and logistically easier to plant smaller stock. Species such as rushes and sedges can be planted from plugs as they are usually aggressive growers and able to quickly establish. Live cuttings (e.g. willow, Red Osier Dogwood) can also be used to quickly establish a shrub component and help stabilize banks. Cuttings can vary in length (typically 1 to 1.5 m in length, with the bottom third buried in the ground). Shrubs should be in 1 or 2 gallon pots and trees should be 0.5 to 1.5 m tall in a large pot. Competition from invasive species and herbivory (e.g. deer browsing, vole girdling or beaver foraging) should be considered. Where Reed Canarygrass or other invasive species are an issue, taller stock should be planted. Taller stock may also negate issues related to deer browse but will not deter beavers. Preferred plant lists for habitat restoration in specific ecosystems should be consulted as well as investigating local plant community diversity, in addition to any regulatory requirements that may apply. All planted species should meet the standards of the BC Landscape and Nursery Association, in addition to other requirements.

3.4.3 Where do I plant?

Plugs can be easily carried in large numbers and planted with a small spade. They should be planted in groups of the same species about 50 cm apart using triangular spacing. Riparian and floodplains may also colonize naturally from seed sources or be revegetated via nearby plant salvages. Shrubs and trees should be planted using triangular spacing at 1 to 2 m and 4 to 6 m respectively. Macrophytes (plants that grow in or near water) are more difficult to establish, but will often colonize naturally from upstream sources.



Planting of riparian restoration for creek in north Burnaby. Photo: DHC.

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3.4.4 When should I plant?

The fastest growth period on the South Coast is from the late spring to early summer. This is the time of year when warm temperatures and abundant sunshine exist along with good water availability. Ideally, plants should already be in the ground by this time. There are two time periods when planting should occur: in the fall, or in the late winter and early spring. During both periods, temperatures are mild and moisture is plentiful to allow for easy planting but plants are generally dormant reducing potential for stress from planting. New plants may be susceptible to frost heave if their roots have not had enough time to establish before the ground begins to freeze. Cuttings should be planted in the dormant period (December to March).

3.4.5 When should a stream and riparian restoration project begin?

Determining the ideal time to begin a restoration project is essential, particularly when working with aquatic ecosystems. Fish and wildlife have different sensitivities to disturbance throughout the year. Projects that could potentially affect the quantity or quality of water at a critical time of the year (e.g. spawning, egg incubation, juvenile rearing) could have unintended consequences.

As a rule, stream channel construction (or other instream work that may affect a watercourse) should occur during periods of no or little flow, at non-critical times of the year (i.e. not during breeding or spawning) when precipitation is reduced and instream flows are reduced. On the South Coast, the lowest risk period for impacts to fish is generally between August 1 and September 15. This is species dependent; therefore, determining which species are present is an important first step. The fish window for Salish Sucker and Nooksack Dace is August 15 to September 15.²⁴

However stream restoration often involves waterbodies which may also support stream breeding amphibians. Sensitive windows for breeding amphibians can start as early as February or March and overlap with the bird nesting window April 1 to July 31 (for most breeding birds). Special timing windows exist for species such as the *fannini* subspecies of Great Blue Heron and many raptors as well as specific amphibian and reptile species. Then there is also the potential that aquatic specialists such as Pacific Water Shrew may be foraging or denning in the area targeted for activity. It is best to consult with local recovery team chairs and or provincial and federal government staff or review regionally specific guidance documents like Develop With Care.²⁵

²⁴ Recovery Strategy for the Nooksack Dace (*Rhinichthys cataractae*) in Canada 2008. Recovery Strategy for the Salish Sucker (*Catostomus* sp.) in Canada 2012.

²⁵ Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia. <http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare/index.html>.

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Example Seasonal Sensitivity Table for Fish and Amphibians*



- most sensitive life history phases [habitat alteration as emergency work only!]

- moderately sensitive life history phases [proceed with extra care]

- least sensitive life history phases [best time to do instream/ inditch work]

Bracketted [] species are species that may or may not be native, that would benefit directly from seasonal protection afforded those species that define the group.

	Instream Works Timing Windows as defined by DFO and MWLAP apply in all cases and FOR ALL SPECIES OCCURRING WITH SALMONIDS	Instream Timing Windows for all watercourses that DO NOT contain SALMONIDS	
	FEDERAL AND PROVINCIAL AUTHORITY	FEDERAL AND PROVINCIAL AUTHORITY	PROVINCIAL AND [FEDERAL] AUTHORITY
	SALMONIDS [COHO (CO), CHUM (CM), RAINBOW TROUT (RB), COASTAL CUTTHROAT TROUT (CCT)]	NON SALMONIDS RED/BLUE LIST	NATIVE AMPHIBIANS RED/BLUE LIST
JANUARY	CO + CM incubation continuing		
FEBRUARY			Early migration of AMGR, AMMA, RAAU, TAGR, HTRE
MARCH	CCT spawning CO + CM hatching CCT incubation		Start of spawning Egg masses extremely vulnerable
APRIL	CO rearing CM migrating to Fraser river	TSB spawning begins	
MAY	CCT hatching CO and CCT rearing	Start of spawning	End of spawning most hatching complete
JUNE			Larvae extremely sensitive
JULY	CO juveniles begin migration from natal streams	End of spawning	Sensitivity decreasing Lung development in larvae proceeding
AUGUST		Larvae extremely sensitive Sensitivity decreasing	Metamorphosis proceeding
SEPTEMBER	CO spawners entering	TSB spawning ends	Metamorphosis of AMMA, HYRE, RAAV, RAAU
OCTOBER	natal streams Start of CO spawning		Aquatic AMGR (Neotnes & older larvae)
NOVEMBER			Very robust, acclimatize well to environmental extremes
DECEMBER	End of CO spawning Start of CO incubation		
KNOWN SPECIES	<i>Oncorhynchus kisutch</i> (CO) <i>Oncorhynchus keta</i> (CM) <i>Oncorhynchus clarkii clarkii</i> (CCT) <i>Oncorhynchus mykiss</i> (RB) [<i>Oncorhynchus tshawytscha</i> (CH)] [<i>Lampetra richardsoni</i> (BL)]	<i>Hybognathus hankinsoni</i> (BMC) <i>Gasterosteus aculeatus</i> (TSB) <i>Cottus asper</i> (CAS) <i>Ptychocheilus oregonensis</i> (NSC) <i>Mylocheilus caurinus</i> (PCC) <i>Richardsonius balteatus</i> (RSC) <i>Catostomus catostomus</i> (LSU) [<i>Cyprinus carpio</i> (CP)] [<i>Ameiurus nebulosus</i> (BNH)] [<i>Carassius auratus</i> (GC)] [<i>Lepomis gibbosus</i> (PMB)] [<i>Pomoxis nigromaculatus</i> (BCB)]	<i>Ambystoma gracile</i> (AMGR) <i>Ambystoma macrodactylum</i> (AMMA) <i>Taricha granulosa</i> (TAGR) <i>Hyla regilla</i> (HYRE) <i>Rana aurora</i> (RAAU) <i>Rana pretiosa</i> (RAPR)* <i>Bufo boreas</i> (BUBO)** [<i>Rana catesbeiana</i> (RACA)] - introduced [<i>Lithobates clamitans</i> (RACL)] - introduced * Not confirmed ** Not seen in Delta since 1996

Note: *Oncorhynchus clarkii clarkii* are year round residents in the Delta creeks in which they inhabit. Most non-salmonid fish and *Ambystoma gracile* (neotenes) are year round residents in the Delta watercourses in which they inhabit.

*This table was developed by R.C. Rithaler for the Corporation of Delta in 2003 to assist with timing windows for instream activities.

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3.5 INCLUDE HABITAT FEATURES: Develop target-species-specific habitat

Micro-habitat refers to the small scale, localized environment that a plant, animal or other organism lives in. The structural features (e.g. stumps, fallen and standing wildlife trees, rock piles) found in these environments are an important, and often overlooked, component of restoration projects. These features provide a diversity of micro habitat that can attract wildlife to a site. This promotes natural dispersal of seeds, spores, and micro-organisms, which in turn increases biodiversity and improves ecological function.

Habitat features should be installed with the following design criteria in mind:

- **Interface:** points of contact between habitat features and soil are where a significant amount of biological activity occurs. Locating features next to existing habitat can encourage movement and colonization.
- **Structure** structural variety increases the number of habitat niches that can be used by a wider diversity of organisms. The size, shape, orientation, and level of decomposition of habitat features can create different environmental conditions that will influence habitat use.
- **Clustering:** habitat features tend to occur in groups rather than be evenly dispersed on a landscape. Clustering features like wildlife trees and downed wood tends to increase their habitat value.

3.5.1 Downed wood in riparian areas

Larger tree trunks that have fallen are often called downed or coarse wood. These provide shelter, feeding sites, and movement pathways for wildlife. It also acts as nurse logs for plants, adds organic matter and nutrients to the soil, and helps to stabilize slopes, reduce erosion, and control sediment runoff. As a critical restoration substrate, downed wood should be retained and reintroduced, wherever possible and appropriate.

Tips for placing Downed Wood:

- Generally speaking, more wood is preferable to less. Target density should be a minimum of 200 pieces per ha (two per 100 m²).
- Sources can be native conifer or deciduous species. The amount of Western Redcedar (*Thuja plicata*) placed near water sources should be minimal due to the amount of auxins (plant hormone) present in the wood.
- Large stumps or logs should be used. Logs should be a minimum of 30 cm diameter and 4 m long.
- Wood should be strategically interconnected, with some extending into the water; single pieces, including stumps, can also be placed in the water to provide cover habitat.
- Wood in varying states of decay should be introduced; because different species decay at different rates, a diversity of micro-habitat can be created over time.
- Logs should be placed cross-slope to aid in erosion and sediment control.

3.5.2 Wildlife trees

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Dead standing trees or ‘planted wildlife trees’ are important habitat features for birds, mammals, amphibians and other organisms. They provide forage, roosting and nesting sites for a diversity of bird species. They also provide future downed wood input. If an excavator is being used on site, this is an ideal opportunity to install wildlife trees.

Tips for placing wildlife trees:²⁶

- Large conifers tend to decay less quickly than deciduous trees; however, a variety of species should be used to provide a range of micro-habitats.
- One third to one half the length of a wildlife tree should be buried to ensure stability.
- Trees should be placed leaning away from structures and people.
- Logs should be a minimum of 40 cm in diameter and 6 m long.
- Wildlife trees should be installed at variable spacing (single trees no closer than 10 m apart) and in clusters (several trees grouped together).

3.5.3 Artificial structures



Wildlife trees installed adjacent to Lynn Creek, and Carving features in wildlife tree, Tynehead Park. Photos: DHC.

²⁶ For some great tips on various types of wildlife tree installations see: Installing Wildlife Habitat Installations — plans for 3 options <http://sporelore.com/installing-snag-wildlife-habitat-installations-plans-for-3-options>.

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Nesting boxes, raptor perches, bat boxes, and artificial cover objects for salamanders are some examples of artificial structures that can be included as part of a restoration. These features should be installed to enhance existing habitat, rather than as a replacement for what is already there. Some species don't like close quarters (i.e. they are territorial) and will not use features if they are too close together. Installing habitat features before planting is started will reduce potential for damage to vegetation.

- Raised nest boxes located on artificial posts or pilings within riparian areas can fill this void, while also providing additional protection from terrestrial predators and human disturbance. Nest boxes should be designed for local cavity nesting birds. On the South Coast, there are over 30 bird species that are known to use nest boxes, including raptors, waterfowl, and songbirds. Some species are endangered, such as purple martin. Installation and maintenance of nest boxes can be coordinated with local stewardship groups.
- Raptor perches and nest tree stands may be considered when there are no trees or other structures nearby. These can be simple structures, often requiring placement of tree stems or artificial poles. Potential predation effects on other managed species should be considered.
- Natural bat roosts are declining, particularly in urban areas. Building bat boxes as part of a stream and riparian project can be successful, as there are usually numerous insects for feeding. Boxes should be installed high up on a wildlife tree or artificial post and be located in an area that receives ample sunshine.
- Amphibian cover objects may include wood placed on the soil surface. Multiple pieces layered overtop one other will provide the desired gaps and hiding areas.
- Hibernacula²⁷ and basking habitat can be created in dug out holes using angular rock and logs. These shelters provide excellent habitat for species such as the Northern Alligator lizard, Terrestrial Garter Snake and Rubber Boa.



Nest boxes that simulate tree cavities often get utilized by a number of species including Northern Flying Squirrels, Screech Owls and waterfowl. They also provide hibernacula for insects. Northern Flying Squirrel in Wood Duck nest box. Photo: Pennsylvania State Department of Conservation and Natural Resources.

²⁷ <http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Snakes-in-Terrace2011.pdf>.

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Bat Roosts

One method of promoting bat roosting habitat or assisting with bat eviction is to build a bat-house. These small wooden houses provide a safe place for bats to roost, have cover from the elements, and have grooves or netting that the bats can easily hold on to. They are most successful when they are combined with bats being excluded from an area. For example, if bats inhabited your attic, and then the attic is sealed so they can no longer use it, bats would be more likely to use a bat-house that was installed nearby.^a With the recent emergency listing of three bat species under the federal Species At Risk Act due to the impacts from white-nosed syndrome, there has never been a more important time to provide habitat for these important natural pest control agents.^b



Bats leaving a freestanding bat box. Photo: New York State Department of the Environmental Conservation.

^a Community Bat Programs of BC – Bat Houses. <http://www.bcbats.ca/index.php/bat-houses>.

^b Bats in Buildings and the Emergency Listing Order.
<http://www.sararegistry.gc.ca/default.asp?lang=En&n=DD955940-1>.

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3.6 MONITOR AND MEASURE: Adapt to challenges and evaluate success

Stream and riparian communities are complex and it is difficult to predict the natural and human caused influences that may affect them. Regular monitoring will help determine whether the channel and instream structures are functioning as intended. The physical stability of the channel, banks and instream features should be assessed. Establishing photo monitoring points that can be compared over time is an excellent way to track physical changes and development of the plant community. The best guide out there has been developed by the US Forest Service . Visual assessment will help to track plant health, identify damage from vandalism and detect any invasive plants and animals that may establish.

Water quality testing provides a baseline to track the condition and health of an aquatic system. Testing should include chemical, physical and biological conditions. Physical and chemical testing should include flow rate, temperature, conductivity, dissolved oxygen, pH, and turbidity. These should be compared to the Canadian Water Quality Guidelines for the Protection of Aquatic Life. Biological conditions in the stream should be monitored by testing for benthic invertebrates. Methods should follow the Ministry of Environment Guidelines for the Sampling of Benthic Invertebrates in British Columbia Streams (2006) or the Federal Canadian Aquatic Biomonitoring Network (CABIN) .



Stream sampling. Photo: Pamela Zevit.

Monitoring should be most frequent for the first three years. However, plan to assess the ecosystem annually for an unlimited number of years to ensure it is healthy and functional. Regular visits will allow you to continue assessing the way in which species use your project site and provide learning opportunities for decades that can be applied to other projects.

3.7 Sharing success

Successful restoration projects are extremely rewarding. When properly planned and executed they provide habitat for target species at risk as well as a multitude of other organisms. They can also help to mitigate the impacts of urban development and provide recreation opportunities. Practitioners should take great pride in their successes which are a function of proper planning and persistent monitoring and care.



Water quality monitoring - volunteer. Photo: Pamela Zevit.

4 CASE STUDIES

Stream and Riparian Restoration



Northern Red-legged Frog- Illustration by Carrielynn Victor

4.1 Dixon Creek Restoration Project, Township of Langley

Project Partners: Dr. Mike Pearson (Design and Construction Supervision), Township of Langley, Langley Environmental Partners Society

Project Description: This restoration project was initiated in 2008 following the purchase of the Dixon House property by the Township of Langley Parks Department in 2004. Reconstruction of 850 m of Dixon Creek and complexing of 200 m of the mainstem Nicomekl River was completed as a public demonstration of stream restoration. Prior to restoration, the creek was suffering from stream incision due to straightened channel, lack of habitat complexity, eutrophication (i.e. excessive nutrient loading resulting in lack of oxygen), high summer water temperatures, high sediment and contaminant loading from roads, and lack of riparian vegetation. Restoration work included creation of riffle-pool habitat, re-meandering of the channel, habitat complexing, and riparian planting. Target species for this project include Coastal Cutthroat Trout and Northern Red-legged Frog (both provincial blue-listed species) in addition to Coho Salmon.

Planning and Implementation: Instream work was completed in two phases; 2008 and 2010 and riparian planting was done by volunteers each fall from 2008 to 2012. In the first phase, a settling pool was excavated at the upstream end with the intention of capturing sediment from road runoff in a convenient location for its periodic removal. A new channel was excavated and complexed in the dry. Spoil was sidecast onto the adjacent field and stockpiled between the new and existing channel for later use in backfilling the existing channel. The channel invert was elevated by a series of constructed riffles relative to the deeply incised existing channel and both banks sloped to create a low flow channel within a broader flood channel. Stripped topsoil was re-spread over the new bank slopes. Large stems of wood were trenched into the banks along the full channel length. Riffles were constructed by keying large (500 to 750 mm) boulders into channel bed to fix elevations and covering them with a mix of 4-10" cobble (100 to 250 mm) and drain rock (20 to 50 mm). The entire channel bed (clay) was then covered with a 100 to 150 mm bed of cobble and drain rock.

The existing channel was diverted after first installing stop nets upstream and then blocking the existing channel so that it drained from the downstream end into the new channel. Backfilling of the existing channel and landscaping of the southwest bank occurred after the channel diversion and a fish and amphibian salvage.

In the second phase, the existing channel was reconstructed in 100 m sections. Following a fish and amphibian salvage, the section was isolated by inserting large steel plates across the channel at each end with an excavator. The creek's flow was pumped around the section while work was completed. The channel was meandered by

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cutting and filling on opposite sides of the channel, and complexed with large stems of wood buried into the bank. A pond, which had previously warmed water to above 30 °C in summer was bypassed, but left connected at one end as an off-channel habitat.

Numerous snags stumps and stems of wood piles were then installed in the riparian areas during both phases. All exposed soils were seeded with a mixture of fall rye and a lowland pasture mix. Riparian planting was completed in October. Invasive Reed Canarygrass was removed manually from some areas prior to planting. Over 1000 riparian shrubs and trees of more than 25 species were planted (mostly in 2 or 5 gallon pots) with assistance from the public and the Langley Environmental Partners Society. All trees and tree-like shrubs were protected from voles with plastic spiral guards and from beaver by encircling with a 1 m diameter page-wire fence stapled to a single 3" fencepost. Salvaged cattails were also planted on a shallow bench on the margin of the settling pool.

Introduced species identified on site include Reed Canarygrass (*Phalaris arundinacea*) and Himalayan Blackberry (*Rubus armeriacus*).

Project Outcomes and Lessons Learned: Post-construction monitoring work has demonstrated adult red-legged frogs and coho salmon use the habitat, but coastal cutthroat trout have not yet been documented. Riparian planting survivorship has been excellent and summer water temperatures in the lower creek have been greatly reduced by the pond by-pass.



Time series. Photos: Mike Pearson.

CASE STUDIES

4.2 Bertrand Creek Restoration Project, Township of Langley

Project Partners: Dr. Mike Pearson (Design and Construction Supervision), Landowner (name withheld), Langley Environmental Partners Society, Habitat Stewardship Program for Species at Risk (partial funding).

Project Description: This restoration project was initiated in 2009 to repair and relocate channels affected by flooding and erosion. The creek flows through agricultural land; in 2007 flood water breached the channel banks and created a secondary channel through a farm field rendering it unfarmable and eroding approximately 1000 m³ of soil downstream. In addition to mitigating future flood damage, channel restoration increased channel length, habitat complexity and riparian buffer width enhancing fish habitat along approximately 500 m of channel. The reach is identified as potential Critical Habitat for Salish Sucker in its SARA Recovery Strategy. Other species present include Nooksack Dace (also SARA listed), Coastal Cutthroat Trout (BC blue list), Coho Salmon, and Steelhead.

Planning and Implementation: This project was completed in 2009 with some repair work being completed in 2010. All channel construction was completed in the dry. The new channel was constructed in a natural meander pattern for a length of 250 m through a 30 m wide riparian corridor. Bankfull width of the channel average five metres and the meander length is 60 m. Bankfull depth averages one metre, but the channel is contoured in accordance with the meander pattern (i.e. deeper on outside of bends). Periodic, larger, deeper pools were excavated in suitable locations and at the confluence with Howe's Creek. Six riffles were constructed using gravel mined from the area and purchased boulders. Each riffle has a drop of 12 to 15 cm for a total drop of 74 cm. Spoil from channel excavation was stockpiled and used to infill the old channel.

Large stems of wood and boulders were used to complex the channel, particularly the larger deep pools. Debris features were placed above flood level or pinned in place with vertical snags with their bases buried at least 2 m deep. Outside bends were stabilized with large stems of wood revetments. Logs were anchored into the bank by burying at least 4 m of trunk and pinning them with vertical log snags. They were angled in a downstream direction and protruding branches were minimized to reduce debris accumulation.

Large stems of wood was placed in the riparian zone, and approximately 20 vertical snags were installed to provide bird perches. Immediately following construction, exposed areas were seeded with fall rye. Where riparian planting was required, target density averaged 1.5 trees (5 gallon) and 3 shrubs (1 to 2 gallon or cluster of 5 whips) per 10 m² of area. Some willow whips were collected on site and some from nearby natural areas; some were also inserted into the revetments during construction (to water table if possible). Willows and all trees were protected from vole damage using commercially available plastic guards and from beaver damage by one metre high, heavy gauge, page wire fencing secured with willow whips or surveyor stakes.

Introduced species identified on site include American Bullfrog (*Rana catesbeiana*), Brown Bullhead (*Ameiurus nebulosus*), Pumpkinseed (*Lepomis gibbosus*), and Fathead Minnow (*Pimephales promelas*) (Pearson pers. comm.).

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Project Outcomes and Lessons Learned: The major challenge in this project was stabilizing the channel for the first winter using soft engineering methods (e.g. no rip-rap). Bertrand Creek carries high winter flows and the drops almost 1 m in elevation over the length of the project, giving it tremendous erosive power. Brush bundles and burlap coffee sacks secured with ground stables were also used to help stabilize slopes. The coffee sacks were overlapped like shingles to avoid current lifting their edges and lent themselves well to placement around large stems of wood features. Additional cobble and round boulder were installed in 2010 to stabilize a few areas that eroded significantly during the first winter.

Post-construction monitoring work has showed that high densities of Salish Sucker and Nooksake Dace are breeding and rearing in the new channel. Coho Salmon, Steelhead and Coastal Cutthroat Trout also spawn and rear in the project. Additional fill planting was completed in 2011.

Beaver damage to riparian plantings (and some commercial blueberry plants) has been a continual problem. Additional beaver protection fencing has been added.



Time series. Photos: Mike Pearson.

