*The **Stewardship** Series*

Shoreline Structures Environmental Design

A Guide for Structures along Estuaries and Large Rivers

NATIONAL LIBRARY OF CANADA CATALOGUING IN PUBLICATION DATA

Adams, Mark A.

Shoreline structures environmental design : a guide for structures along estuaries and large rivers

(The Stewardship Series)

"This manual is a publication of the Habitat and Enhancement Branch of Fisheries and Oceans Canada and the Canadian Wildlife Service of Environment Canada."—p.3.
Includes bibliographical references.
Issued also in print format.
Mode of access : WWW site of Environment Canada.
ISBN 0-662-33045-5
Cat. no. En4-7/2002E-IN

1. Shorelines – Environmental aspects – British Columbia.
2. Waterfronts – Environmental aspects – British Columbia.
3. Estuarine area conservation – Environmental aspects – British Columbia.
4. Coastal zone management – British Columbia.
5. Habitat conservation – British Columbia.
I. Canada. Environment Canada.
II. Fisheries and Oceans Canada. Habitat and Enhancement Branch.
III. Canadian Wildlife Service.
IV. Title.
V. Series: Stewardship series.

GB460.C3A32 2003 333.91'7'09711 C2003-980100-4

PUBLICATION CITATION

Adams, M.A. 2002. **Shoreline Structures Environmental Design: A Guide For Structures Along Estuaries and Large Rivers.** Fisheries and Oceans Canada, Vancouver, BC and Environment Canada, Delta, BC. 68p + appendices.

ACKNOWLEDGEMENTS

Funding for this publication was provided by Fisheries and Oceans Canada and Environment Canada

Project Administrators
Otto E. Langer, Fisheries and Oceans Canada
Dave Harper, Fisheries and Oceans Canada

Project Manager and Author
Mark A. Adams, ECL Envirowest Consultants Limited

Technical Editors and Contributors
Gary L. Williams, G.L. Williams and Associates Ltd.
Peter Morgan, Hay and Company Consultants Inc.

Graphic Design and Layout
Karen E. Asp, ECL Envirowest Consultants Limited
Mark A. Adams, ECL Envirowest Consultants Limited

Graphic Technician
Michael G. Macfarlane, ECL Envirowest Consultants Limited

Illustrations
Cover: Karen E. Asp, ECL Envirowest Consultants Limited
Chapters: Pete Willows, ECL Envirowest Consultants Limited

Photographs are Reproduced with Permission from
Mark A. Adams, ECL Envirowest Consultants Limited
Scott Barrett, BC Ministry of Water, Land and Air Protection
Eric D. Beaubien, ECL Envirowest Consultants Limited
R. Wayne Campbell, Wayne Campbell and Associates
Canadian Wildlife Service
Robert Cochrane, ECL Envirowest Consultants Limited
John M. Cooper, Manning, Cooper and Associates
Fraser River Port Authority
John Grindon, Brinkman & Associates Reforestation Ltd.
Rick Harbo, Fisheries and Oceans Canada
Myles Hargrove, Shady Creek Native Plants and Environmental Contracting Ltd.
Kon Johansen, Fisheries and Oceans Canada
Rachael E. Jones, ECL Envirowest Consultants Limited
Otto. E Langer, Fisheries and Oceans Canada
Art McLeod, Exceptional Photography
Bruce Peel, Peel's Nurseries Ltd.
Province of British Columbia
Rolf W. Sickmuller, ECL Envirowest Consultants Limited
Gary L. Williams, G.L. Williams and Associates Ltd.

Contents

Preface

Shoreline Structures Environmental Design – A Guide for Structures along Estuaries and Large Rivers is a product of the Fraser River Action Plan, an initiative of Canada's Green Plan. The Fraser River Action Plan encouraged partnerships between government and non-government stewards of the environment, facilitated pollution reduction and clean up, and promoted better science to make the Fraser River a healthier environment.

This guide was designed as a Stewardship Series publication. It is somewhat different from the other publications in the series in that, in addition to planning and management guidance, this guide also provides detailed environmental design concepts. Its target audience is the same as the other Stewardship Series publications; local governments, land owners, developers and community stewardship groups can all benefit from understanding and adopting the design principles outlined in this guide.

The environmental design concepts presented in this publication will help proponents to mitigate the negative impacts that shoreline developments can have on fish and wildlife habitats. This guide will also help the proponent to recognize that shoreline environments are composed of many interdependent biological and physical components and that impacts to any one component will have a decided effect on others.

The lower Fraser River and its estuary were the original focus of this guide; however, during its development, it became apparent that many of the environmentally friendly design concepts presented in this guide would be generally applicable to any large river or estuary. Thus, despite the numerous references to the Fraser River and its estuary, the guide can be applied to shoreline projects within large rivers and estuaries throughout coastal British Columbia.

This guide would not have been possible without the collaborative effort of staff from Fisheries and Oceans Canada, Environment Canada (Canadian Wildlife Service), North Fraser Port Authority, Fraser Port Authority, and the B.C. Ministry of Water, Land and Air Protection. Their contributions are greatly appreciated.

Introduction 1

1.1 Shoreline Environments

British Columbia's coast is a composite of numerous shoreline environments that support important habitats for fish and wildlife. Estuaries and the lower reaches of large rivers are two of the more conspicuous of these environments.

An estuary may be defined as a semi-enclosed body of water with an open connection to the ocean, where at its seaward margin seawater is measurably diluted by fresh water from land drainage, and at its landward margin water levels are measurably altered by tides.

Estuaries often occur within sheltered bays, inlets and coves. These sheltered environments reduce mixing of fresh and salt waters, and in combination with seasonal variations in fresh water discharge and the daily fluctuation of tides, create distinct zones of salinity from the mouth of the stream or river to the open ocean. Large quantities of sediment are discharged into estuaries by larger streams and rivers, creating physically complex and dynamic deltas. Fluctuations in water levels, attributable to seasonal variations in discharge and tides, add to the complex and dynamic nature of estuaries. The transitional environments created by distinct zones of salinity, fluctuating water levels and the deposition of sediments sustain important shoreline habitats for a rich assemblage of fish and wildlife species.

The lower reaches of rivers often share many physical characteristics with estuaries. Seasonal variations in discharge result in concurrent fluctuations in water levels. The deposition of sediments creates a complex of floodplain features. Islands, bars and flood channels are features common to both riverine floodplains and estuarine deltas. The shorelines of estuaries and the lower reaches of large rivers form a large contiguous corridor that is utilized by many fish and wildlife species.

1963

1992

Figure 1.1 The conversion of natural shorelines to developed areas has resulted in a considerable loss of fish and wildlife habitat (Ladner Channel, Main Arm distributary channel, Fraser River).

Estuaries and the lower reaches of rivers are characterized by low grades and fertile soils. These characteristics, together with the sheltered nature of these coastal features, render estuaries and the lower reaches of rivers ideal locations for human activities. The development of natural shorelines to support agricultural, urban and industrial uses has often resulted in a substantial loss of fish and wildlife habitat over time (Figure 1.1).

Historically, the development of natural shorelines occurred without effective mitigation of impacts to fish and wildlife habitats. Only since the mid-1980's have shoreline development projects incorporated environmental design criteria that effectively mitigate impacts. Fisheries and Oceans Canada's "Policy for the Management of Fish Habitat" (1986) was instrumental in guiding this change in design approach. Effective habitat conservation policies of other regulatory agencies, such as the Canadian Wildlife Service of Environment Canada, implemented independently or in collaboration with Fisheries and Oceans Canada's habitat policy, have also substantially reduced the impacts of shoreline development projects upon fish and wildlife habitats.

Environmental design criteria that effectively mitigate impacts to habitats have not been readily accessible to proponents of development. Basic environmental design criteria should be readily accessible to all individuals involved in the planning and design of shoreline projects. Accessibility promotes the application of these criteria and, in turn, the conservation and protection of shoreline environments.

1.2 Purpose

The ***Shoreline Structures Environmental Design*** manual was specifically developed to consolidate and present basic environmental design criteria for developments within shoreline environments and assist proponents to understand how these criteria can be utilized to conserve and protect fish and wildlife habitats.

1.3 Scope

The ***Shoreline Structures Environmental Design*** manual provides basic environmental criteria for planning and designing shoreline development projects. As the character of projects and shoreline environments varies greatly, the manual is not a stand-alone document. Site-specific investigation and consultation with environmental agency personnel will be required to properly assess project feasibility.

Although many of the criteria presented in this manual are useful for shoreline development projects, they are not to be construed as rules that must be rigidly adhered to by project planners and designers. Every project is unique in its design constraints and opportunities. Consideration of these constraints and opportunities has lead to innovations in project design that have advanced mitigation technology. The criteria presented in this document are intended to assist, not hinder, the development and evolution of innovative mitigation design.

This manual is a publication of the Habitat and Enhancement Branch of Fisheries and Oceans Canada and the Canadian Wildlife Service of Environment Canada. Accordingly, the manual presents design criteria that facilitate the conservation of fish and wildlife habitats. In some instances, these criteria may not be consistent with design criteria endorsed and promoted by other regulatory agencies. Consultation with all agencies that have regulatory authority with respect to the project, including Fisheries and Oceans Canada and Environment Canada, will typically be required to achieve a comprehensive design that adequately addresses all regulatory requirements.

1.4 Content Overview

The ***Shoreline Structures Environmental Design*** manual is comprised of six chapters and three appendices. Each chapter is capable of being a stand-alone reference on the subject matter presented. As such, each chapter may be amended, as required, independent of the other chapters. The manual is bound to allow the ready replacement of amended chapters. However, the manual is of greatest use when all chapters are considered collectively during the planning and design of a project.

Chapter 1 'Introduction' introduces the reader to the environmental setting and values of estuaries and large rivers. It introduces the purpose of the manual, specifically to provide basic environmental design criteria for projects that have the potential to impact shoreline fish and wildlife habitats.

Chapter 2 'Habitat Structure and Function' examines the relationship between structure of conspicuous shoreline environments and associated fish and wildlife habitat functions. Subsequent chapters elaborate further upon this relationship as design criteria are presented.

Chapter 3 'Legislation and the Project Review Process' identifies the main regulatory agencies and their respective legislative mandates as they apply to shoreline development. Design impact mitigation and compensation is defined and explained. A conventional project review process is described, with special reference to Authorizations pursuant to Subsection 35(2) of the Federal *Fisheries Act*.

Chapter 4 'Facilities and Structures' presents design criteria intended to mitigate impacts of shoreline facilities and structures on fish and wildlife habitats. Information regarding structure, location and configuration, and material types is presented.

Chapter 5 'Dikes' presents environmental design criteria for dike design that do not detract from the dike's primary function of flood protection.

Chapter 6 'Establishing Vegetation' emphasizes a design philosophy that seeks to create the best environment possible for establishing vegetation as a component of productive fish and wildlife habitat. Site preparation, species and stock types are presented.

Appendix A 'Glossary' provides detailed definitions of technical terms presented by this manual.

Appendix B 'Bibliography and Photographic Credits' acknowledges sources of information utilized by this manual. Cited and general sources are referenced. Credits are afforded to those individuals and organizations that have granted permission to reproduce their photographs in this publication.

Appendix C 'Common Wetland and Riparian Plants' familiarizes the reader with common wetland and riparian plant species often used in impact mitigation and compensation habitat projects.

Habitat Structure and Function 2

2.1 Introduction

Habitat may be defined as an environment an organism utilizes for all or part of its life. Obvious habitats are those directly utilized by organisms, such as shrub woodland used for nesting by birds, or tidal channels explored by fish for food. An environment, however, need not be directly utilized by an organism to be habitat.

The instream environment is obvious habitat for juvenile salmonids. The riparian environment, comprised of the upland area in immediate proximity to the stream channel, although less obvious, is also habitat. Vegetation within the riparian environment assists in the regulation of stream temperature through shading and thermal insulation. It deposits organic matter into the stream channel that is scavenged by detritus-eating insects that are in turn preyed upon by salmonids. Vegetation facilitates a stable flow regime by regulating the delivery of surface and subsurface drainage into the stream. Both the stream and riparian environments are habitat for juvenile salmonids.

Structure is an important component of habitat. In essence, structure is the arrangement of physical elements in space. Natural structure is characterized by primary and secondary physical elements. Examples of primary elements include topography and bathymetry, mineral soil texture and stratification, seasonal and tidal fluctuations in water levels, and water currents and waves. Secondary physical elements are those attributable to plants and animals. Examples of secondary elements include peat soil within sedge marshes, canopy layering within riparian woodlands, and ponding caused by beavers. The complexity of structure is dependent upon the presence and interaction of these elements.

Shoreline environments support habitat functions important to the vigour and survival of organisms. A function is the interaction between an organism and its environment. When young waterfowl hide within marsh vegetation to escape a predator, the function provided by the vegetation is refuge. The vegetation does not provide a function unless the waterfowl use it. Such is the scenario for all organisms and their environments; the ability of an environment to sustain a function, and be habitat, is dependent upon the ability of an organism to use that environment.

Structure is a strong determinant of the type and number of habitat functions that can be sustained by an environment. In general, if the complexity of structure is increased, the number of functions that can be sustained by an environment is also increased.

The following sections examine the relationship between the structure of conspicuous shoreline environments and associated fish and wildlife habitat functions.

2.2 Tidal Flats

Tidal flats occur throughout the lower estuary. They are conspicuous features of the delta front (Figure 2.1). Flats may be composed of clays, muds, sands, gravels or cobbles. Often a flat is composed of several intergrading zones of substrates.

Different types of substrates provide different structural environments for organisms. Each substrate type is characterized by a distinct assemblage of organisms that live within and upon the surface of the sediments (Figure 2.2). The species composition of the assemblage is further influenced by the prevailing salinity and tidal regimes.

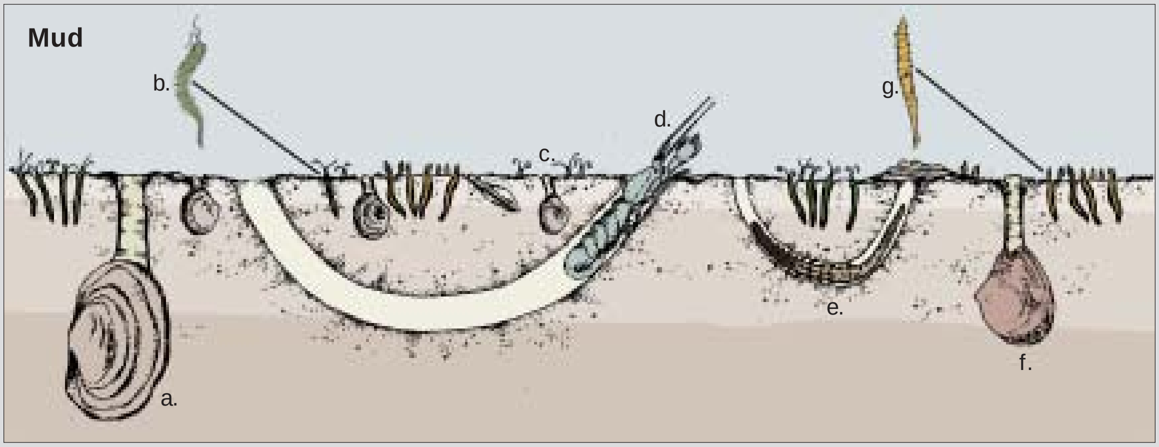
A notable characteristic of flats is the general absence of vascular plant species. Eelgrass (*Zostera marina*) often occurs along the waterward margin of tidal flats, at and about local low water. Intertidal marsh typically occurs along the landward margin of flats.

Figure 2.1 Tidal flats of Boundary Bay, Fraser River estuary.

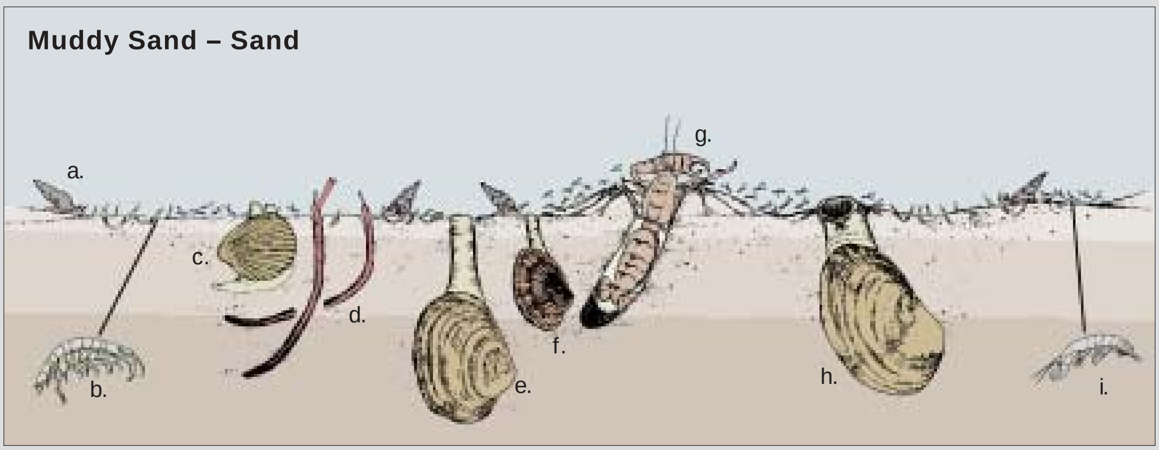
Non-vascular plants are often common inhabitants of tidal flats. Unicellular and filamentous algae often occur within fresh and low salinity-brackish flats. High salinity-brackish and salt flats, when large gravels and cobbles are available as anchors, often display rockweed (*Fucus distichus*) and sea lettuce (*Ulva* spp.). The presence of algae enhances the structural complexity of tidal flats.

A constant theme for all estuarine tidal flats is that they receive, to varying degrees, a constant 'rain' of detritus. Detritus is comprised of decomposing animal and plant matter and the bacteria and fungi that inhabit and feed upon it. Detritus is the foundation of the food web of estuarine ecosystems. The majority of the tidal flat organisms, both in terms of number of species and number of individuals, consume detritus.

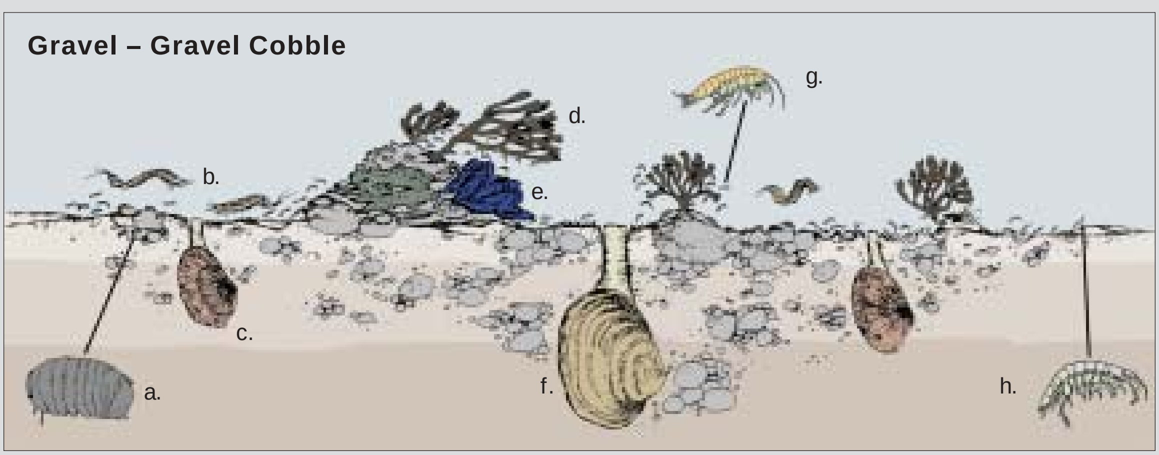
The availability of detritus to deposit and filter feeders is dependent upon the type of substrates that comprise the flat. These substrates are, in turn, dependent upon the prevailing sedimentation regime. Within low energy environments, where fine substrates (e.g. clays, muds and fine sands) settle and are retained, detritus comprises a significant fraction of surficial sediments. It is loosely consolidated and readily suspended within the



a. bent nose clam (*Macoma nasuta*); b. spionid worm (*Spionidae*); c. Baltic clam (*Macoma balthica*); d. mud shrimp (*Upogebia pugettensis*); e. lugworm (*Abarenicola pacifica*); f. soft shell clam (*Mya arenaria*); g. capitellid worm (*Capitellidae*)

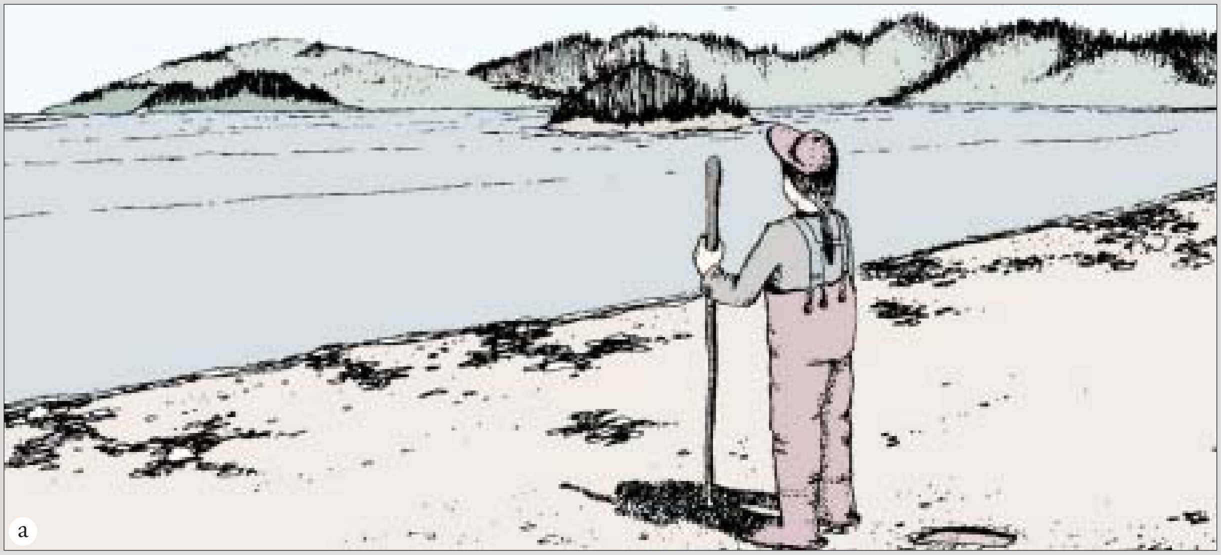


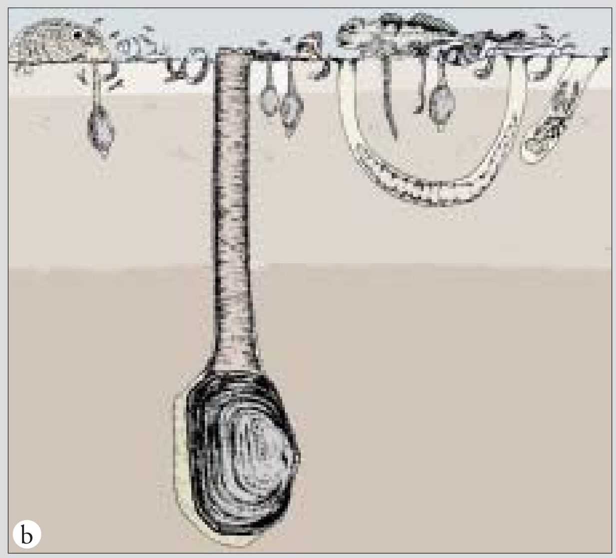
a. screw shell (*Batillaria attramentaria*); b. corophid amphipod (*Corophium* spp.); c. cockle (*Clinocardium nuttalli*); d. proboscis worm (*Glycera* spp.); e. butter clam (*Saxidomus giganteus*); f. littleneck clam (*Protothaca staminea*); g. ghost shrimp (*Neotrypaea californiensis*); h. gaper clam (*Tresus capax*); i. tanaid (*Leptochelia* spp.)



a. pill bug (*Gnorimosphaeroma oregonense*); b. nereid worm (*Nereis* spp.); c. littleneck clam (*Protothaca staminea*); d. rockweed (*Fucus distichus*); e. bay mussel (*Mytilus edulis*); f. butter clam (*Saxidomus giganteus*); g. gammarid amphipod (*Eogammarus confervicolus*); h. corophid amphipod (*Corophium* spp.)

Figure 2.2 Generalized brackish tidal flat assemblages of organisms according to substrate type.





Structure: a scaled perspective

Structure is often the fundamental element of habitat. The observed complexity of structure is dependent upon the scale at which an environment is scrutinized. At first glance (a), tidal flats appear generally void of structure relative to nearby marshes and eelgrass meadows. Upon closer examination (b), the structure of the upper sediment horizon is apparent, with different strata sustaining a myriad of organisms, many of which are important food items for both fish and wildlife. At a greater distance (c), it is readily apparent that the tidal flats are part of a greater complex of habitat types, which interact to address the many habitat requirements of fish and wildlife. In examining structure, the investigator must be aware of the different scales of structure that occur, and how structure at many scales contributes to the biological productivity of shoreline environments.

water column, and is therefore easily retrieved and consumed by deposit and filter feeders. Within high energy environments, coarse sediments (e.g. coarse sand, gravels, and cobbles) dominate the tidal flat surface. Detritus is often not readily available at the surface. It may be found within the interstices of coarse sediments where these localized low energy environments allow detritus to settle. This detritus is available to deposit feeders that can burrow within these substrates. Specialized physical and behavioural adaptations allow specific organisms to access detritus within specific substrates. As a result, the type of organism that may be found on a tidal flat is often dependent upon the availability of detritus as food.

Detritus feeders, and the organisms that feed upon them, constantly modify the tidal flat environment. Conspicuous signs of animal activity include tracks, holes, depressions and mounds (Figure 2.3). The fecal pellets of tidal flat inhabitants are deposited on the surface, forming a flocculent layer that is both food and living space for others. The activity of organisms increases the structural complexity of sediments. This change in complexity often alters the suitability of substrates for particular organisms. It may increase or decrease the number of species or number of individuals that may inhabit substrates. Organisms, through modification of the structural complexity of substrates, are often strong determinants of the assemblage of organisms that may inhabit a tidal flat.

2.3 Eelgrass Meadows

Eelgrass grows in firm mud to sand substrates within low energy environments at depths between +1.8 m and -6.6 m chart datum (Figure 2.4). It occurs within waters characterized by salinities of 10 to 30 grams of salt per liter of water (10 to 30 parts per thousand). The upper limit of intertidal distribution is attributable to desiccation. The lower limit of distribution is determined by a number of contributing factors including substrate type, energy regime, and light intensity.

Figure 2.3 Tracks, holes, depressions and mounds created by tidal flat inhabitants.

Eelgrass meadows (Figure 2.5) stabilize sediments and provide refuge and food for a vast array of organisms. In summer months, the blades of eelgrass are colonized by large numbers of diatoms, small single celled algae that form a fuzzy brown film. Detritus and unassociated bacteria soon become incorporated in this film. This diatom-detritus-bacteria film, together with decaying eelgrass leaves, is an important food source for many protozoans, microscopic worms, and small crustaceans that are, in turn, food for other organisms. Eelgrass provides the structure upon which the film is established.

Figure 2.4 Eelgrass growing within firm sand substrates.

Juvenile chum salmon (*Oncorhynchus keta*) are especially dependent on eelgrass. Eelgrass sustains two key functions of productive juvenile salmon habitat: refuge and food. The stems and blades of eelgrass provide excellent cover. Eelgrass meadows sustain many small sediment-dwelling invertebrates at densities far greater than that of adjacent unvegetated flats. Harpacticoid copepods are one of the more common of these invertebrates. These small crustaceans are the most important prey item of juvenile chum salmon during their residency within estuaries.

The high numbers of harpacticoid copepods found within eelgrass meadows are a function of the structural complexity of the eelgrass stem-root-rhizome-sediment zone (Figure 2.6). This zone extends from immediately above the surface of the sediments to an approximate depth of 10 cm. The complex of twisted roots, rhizomes and shoots provides refugia for copepods from currents; many of the small crustaceans would otherwise be carried off as drift. This complex also captures and retains detritus, a key food item for copepods.

The localized concentration of copepods provides juvenile chum salmon with a readily exploitable food source within a system that also provides these fish with ideal refuge from predators. The structure provided by eelgrass

Figure 2.5 Eelgrass meadows of Boundary Bay, Fraser River estuary.

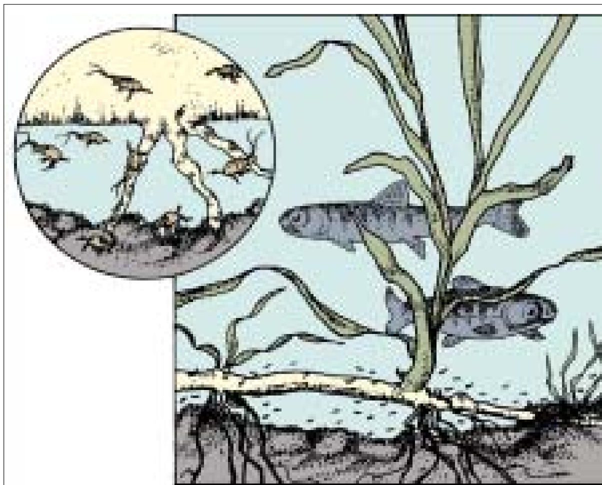


Figure 2.6 High numbers of harpacticoid copepods occur within the stem-root-rhizome-sediment zone of eelgrass.

systems sustains important rearing functions for juvenile chum salmon.

The dominant herbivores in eelgrass systems are waterfowl. Black brants (*Branta bernicla*), Canada geese (*Branta canadensis*), American wigeons (*Anas americana*), scoters (*Melanitta* spp.) and canvasbacks (*Aythya valisineria*) feed on the blades of eelgrass. While staging during migration, large flocks can consume a substantial volume of eelgrass. Localized foraging can cause considerable thinning of eelgrass, in some instances sufficient to create discernable open water patches within a meadow. The creation of patches increases the structural complexity of the meadow. Not only do patches differ structurally from adjacent stands of eelgrass, edges created along the interface of patches and eelgrass stands introduce an additional structural element to the meadow.

Edges provide functions for species characteristic of the interfacing elements of open water and eelgrass stands. Some of these species may be specialists of edge environments. For example, species may use open water for feeding forays, readily retreating into the eelgrass for refuge when threatened by predators.

Numerous species of fish also use eelgrass meadows for spawning. The use of eelgrass for spawning can be especially pronounced. Pacific herring (*Clupea harengus pallasi*) use the blades of eelgrass as a spawning medium. Suspended within the water column, the blades are readily accessible to females. A single female herring may deposit from 9000 to 38000 adhesive eggs directly onto the blades (Figure 2.7). Eelgrass can carry more than 500 eggs per linear 25 mm of blade. The value of eelgrass as a spawning medium is attributable to the structure provided by the blades.

Figure 2.7 Eelgrass is a common spawning medium for herring.

2.4 Tidal Marshes

Tidal marshes vary in plant species composition and diversity throughout estuaries. Variation can be rather dramatic within larger estuaries. For example, the tidal marshes of the Fraser River estuary may be categorized as either lower or upper estuary marshes according to the composition and diversity of plant species. The geographical boundary between these two marsh categories appears to be related to the upstream limit of the salt wedge within the estuary. Lower estuary marshes occur downstream of this location while upper estuary marshes occur upstream of this location. The salt wedge is a primary structural element that appears to determine species composition and dominance within estuarine marshes.

2.4.1 Lower Estuary Marshes

Marshes of the lower estuary are characterized by distinctive vegetation zones that occur along a vertical gradient. Substrate elevations determine the extent and duration of tidal inundation and, in turn, the species that inhabit these zones. A single species typically dominates each of these elevational zones.

Salt, brackish and fresh tidal marshes occur within the lower estuary (Figure 2.8). Each type is defined by the prevailing salinity regime and characterized by a distinct assemblage of dominant plant species.

The southern margin of the delta front of the Fraser River estuary is characterized by high salinities within both interstitial soil and ambient waters. Salt marsh is the dominant marsh type and is characterized by species that can tolerate high salinities. Such species include saltgrass (*Distichlis spicata*), pickleweed (*Salicornia virginica*) and arrowgrass (*Triglochin maritimum*). Dune barley (*Elymus mollis*) occurs within the higher elevations of salt marshes where well draining sands and gravels prevail.

Brackish marsh is the dominant marsh type within the downstream-most reaches of the main distributary channels of the estuary. Intermediate salinities occur within both interstitial soil and ambient waters of brackish marshes. Characteristic species of brackish marshes include Lyngby's sedge (*Carex lyngbyei*), Baltic rush (*Juncus balticus*), tufted hairgrass (*Deschampsia cespitosa*), American threesquare (*Scirpus americanus*), softstem bulrush (*Scirpus validus*), hardstem bulrush (*Scirpus acutus*), and, despite its name, salt marsh bulrush (*Scirpus maritimus*).

Fresh marshes are located within the distributary and main channels of the Fraser River several kilometres upstream of the delta front where tidal influence is still pronounced. Characteristic species of the fresh marsh type include creeping spike rush (*Eleocharis palustris*), softstem bulrush, hardstem bulrush, Lyngby's sedge, broadleaved cattail (*Typha latifolia*) and a variety of grasses, including reed

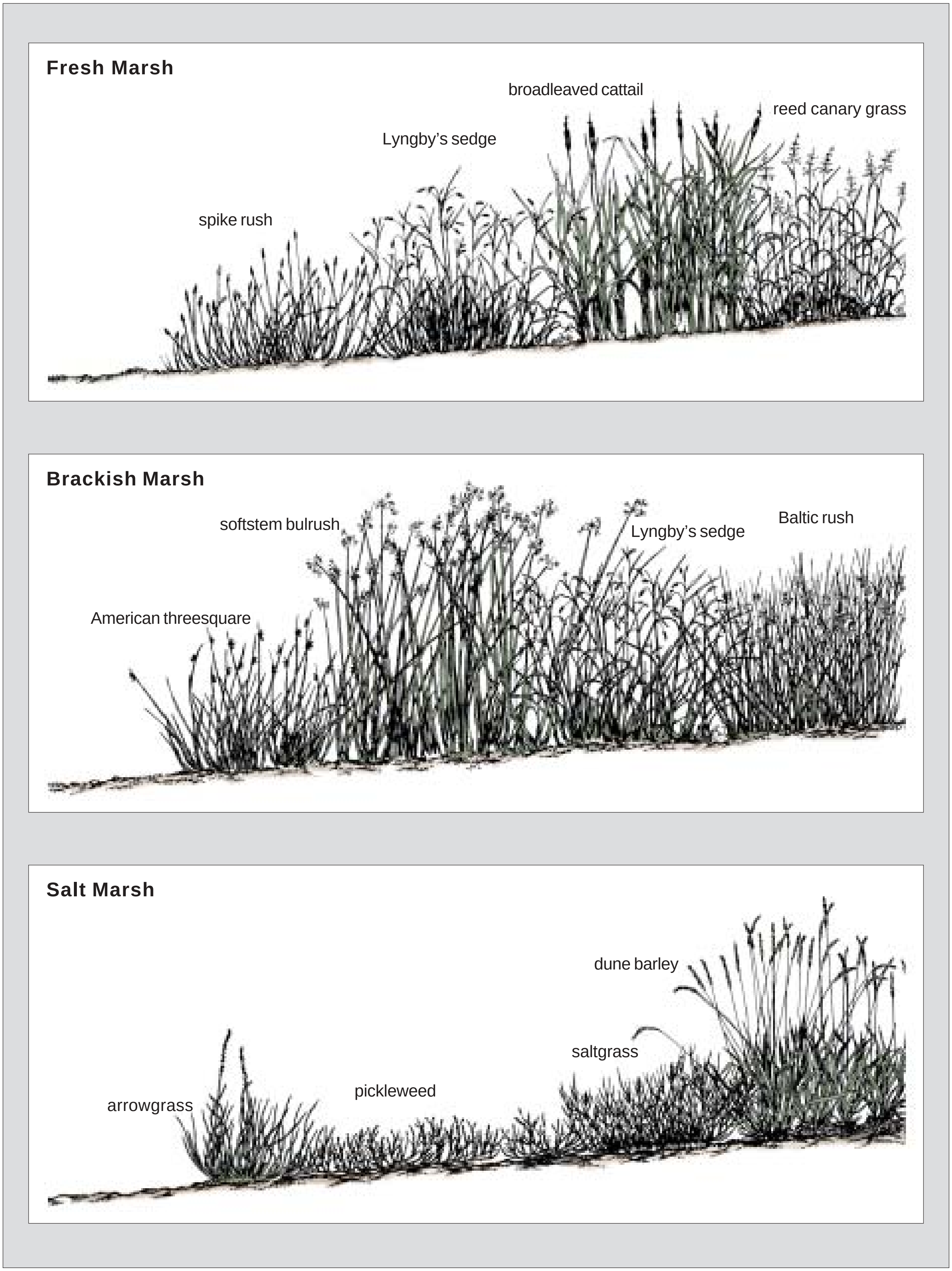


Figure 2.8 Typical species composition and zonation of tidal marshes within the lower estuary of the Fraser River.

canary grass (*Phalaris arundinacea*) and mannagrass (*Glyceria* spp.).

The plants that dominate salt marshes do so because they are able to cope with the physiological stresses imposed by high salinities and extended periods of tidal inundation. It is the tolerance of, and not the preference for these environmental conditions that allows these plants to dominate the assemblage.

Interstitial soil and ambient water salinities decrease with increasing distance upstream of the delta front. The decreasing role of salinity as an environmental stress removes the competitive advantage of those species tolerant of high salinities. Within brackish environments, salt marsh dominants are replaced by other species tolerant of low salinities. Due to their tolerance of low salinities, brackish marsh species are conferred a competitive advantage over many fresh marsh species.

The transition from brackish to fresh water environments is also accompanied by a change in the assemblage of dominant species. Tolerance of low salinities is no longer a competitive advantage. The change in dominant species, however, is not as drastic as that which accompanies the transition from salt to brackish marsh. Some species, such as Lyngby's sedge, maintain dominance within a specific zone. These species possess other characteristics, such as a greater tolerance for tidal inundation, that confer them a competitive advantage over other fresh marsh species. Regardless of the assemblage of dominant species, the distinct zonation of dominants characteristic of salt and brackish tidal marshes is maintained within the fresh tidal marshes of the lower estuary.

The habitat functions provided by tidal marshes for fish and wildlife are dependent upon marsh type. For example, salt tidal marshes possess poor vertical structure; the plants are short in habit. For many small perching birds, these marshes are inadequate for nesting and refuge. In contrast, brackish and fresh tidal marshes are often used extensively for nesting and refuge. Broadleaved cattail, softstem bulrush and hardstem bulrush provide good vertical structure for nesting and refuge. Through its influence on the type of tidal marsh expressed, the prevailing salinity regime determines the habitat functions provided for fish and wildlife.

2.4.2 Upper Estuary Marshes

The upper estuary is characterized by periods of tidal inundation that are shorter in duration than those periods characteristic of the lower estuary. The decreased duration of tidal inundation removes the competitive advantage of plant species that can tolerate extended periods of inundation. The decrease in tidal inundation impacts both the species composition of marshes and the prevalence of distinct zones of dominant species along a vertical gradient.

The removal of the stress of extended inundation allows a greater number of species to compete for space within the intertidal zone. As a result, many species that are also common to non-tidal fresh wetlands are prevalent within the fresh tidal marshes of the upper estuary. Such species include woolly bulrush (*Scirpus cyperinus*), beaked sedge (*Carex rostrata*), water sedge (*C. aquatilis*), shore sedge (*C. lenticularis*), reed canary grass and bluejoint reed grass (*Calamagrostis canadensis*). Fresh marshes of the upper estuary are characterized by a relatively high diversity of species. Distinctive zones of dominant species organized along a vertical gradient are rarely encountered. Other environmental factors, such as grade, soil type and saturation, often have a greater influence on species composition and dominance than tidal inundation.

2.5 Riparian Woodlands

Riparian woodlands occur within, and in proximity to, shoreline environments. Species composition and dominance is related to the influence of both tidal and riverine water level regimes. Three riparian woodland types may be identified within estuaries, namely tidal swamp, floodplain woodland and high water woodland.

2.5.1 Tidal Swamp

Tidal swamps occur within the highest elevations of the intertidal zone, where tidal inundation is of limited duration and occurs, at most, during every other high tide event. The plant assemblage is dominated by shrubs such as willow (*Salix* spp.) (Figure 2.9), red osier dogwood (*Cornus stolonifera*), ninebark (*Physocarpus capitatus*), black twinberry (*Lonicera involucrata*), cascara (*Rhamnus purshiana*) and hardhack (*Spiraea douglasii*). Trees, such as red alder (*Alnus rubra*) and black cottonwood (*Populus trichocarpa*) inhabit the highest elevations of tidal swamps. Where there are breaks in the cover of the shrubs, marsh species often dominate. The structure provided by the marsh-woodland complex affords nesting opportunities for small passerines and waterfowl.

2.5.2 Floodplain Woodland

Floodplain woodlands lie above the normal high tide elevation (Figure 2.10). They are flooded during freshet and extreme storm events. Floodplain woodlands are often characterized by a mix of deciduous and coniferous trees. Dominants of the species assemblage include red alder, black cottonwood and western redcedar (*Thuja plicata*). Shrub species that may occur along the perimeter or beneath the tree canopy include willows, Indian plum (*Osmaronia cerasiformis*), red elderberry (*Sambucus racemosa*), red osier dogwood, black twinberry, snowberry (*Symphoricarpos albus*), ninebark, salmonberry (*Rubus spectabilis*) and thimbleberry (*R. parviflorus*).

Large trees within floodplains are often used by a variety of bird species. Eagles and hawks often nest within the crotch of primary branches near the crown of large black cottonwoods. Herons establish rookeries throughout large stands of trees (Figure 2.11). Western redcedars are often selected for nesting and roosting by large owls. Cavity nesters utilize black cottonwoods extensively (Figure 2.12).

2.5.3 High Water Woodland

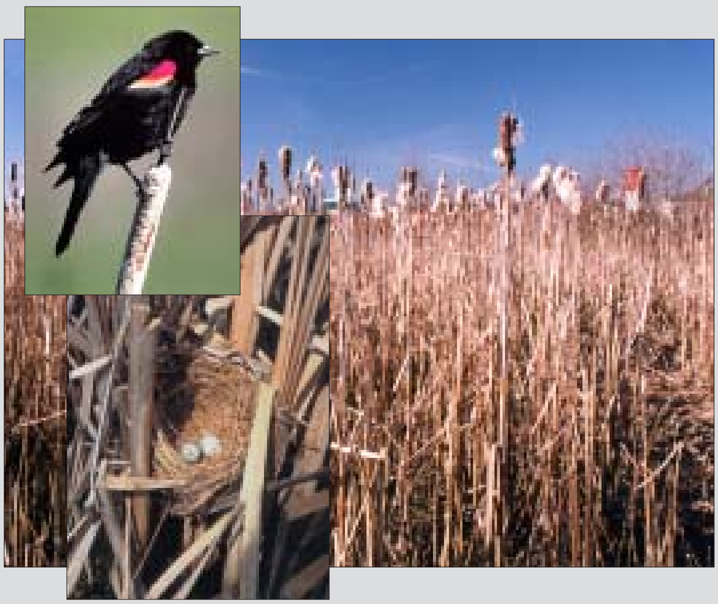
High water riparian woodlands are defined by stands of shrubs and trees above the normal high water mark of the shoreline environment. The assemblage of plants consists of species from both floodplain and

Figure 2.9 Willow dominated tidal swamp, Bedford Channel, Fraser River.

Figure 2.10 Cottonwood dominated floodplain woodland, tidal reach of Kanaka Creek.

Habitat partitioning: selective use of structure

Natural shoreline environments typically sustain diverse assemblages of plants. The structural elements of these assemblages are dependent upon the plant species that comprise each assemblage. Partitioning of these elements by wildlife allows for the compatible use of shoreline habitats by several species. Such use is exemplified by three bird species that often nest along shorelines. Yellow-headed blackbirds (*Xanthocephalus xanthocephalus*; above) prefer to nest amongst stems of softstem or hardstem bulrush, or mixed stands of bulrush and broad-leaved cattail. Cattail stands are the preferred nesting sites of red-winged blackbird (*Agelaius phoeniceus*; centre). Brewer's blackbirds (*Euphagus cyanocephalus*; below) may be found nesting within shrub swamps and riparian thickets.



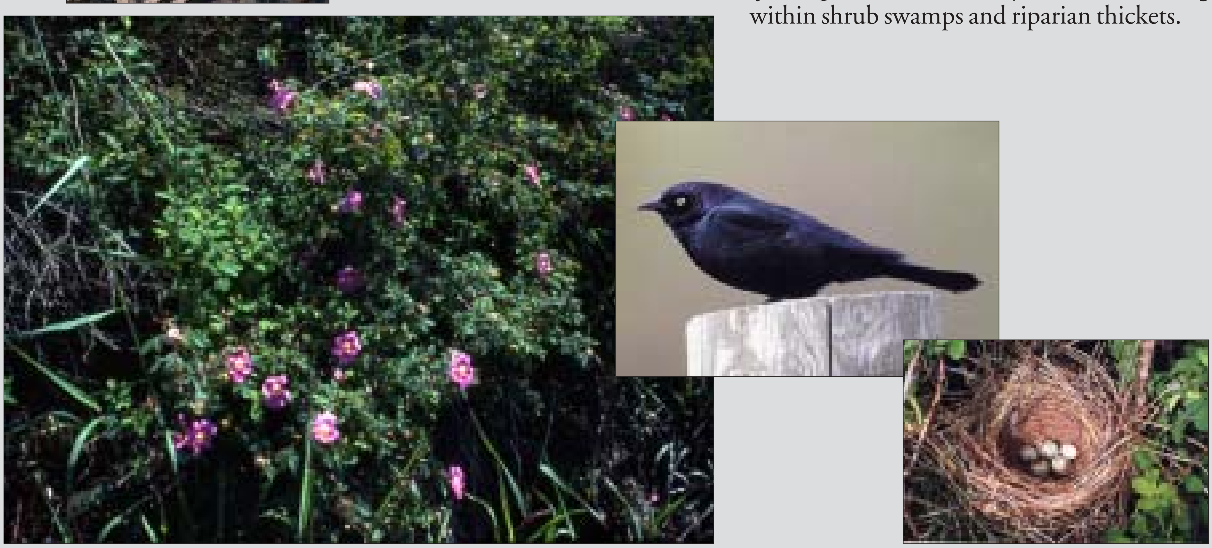


Figure 2.11 Heron rookeries often occur within floodplain woodlands.

upland plant communities. Typically, as the landward distance from the highwater mark increases, the interaction between the water table and plants decreases. As a result, a transition in the composition of species and the habits expressed by individual plants also occurs with increasing distance from the high water mark. The number of species and the number of habits expressed determines the structural complexity of a woodland. Generally, structural complexity increases with an increase in either the number of species or the number of habits expressed.

Structural complexity is further enhanced at the interface between riparian woodland types. The areas defining the interface, or ecotones, are transitional environments that are important determinants of the overall value of riparian woodlands as fish and wildlife habitat. An ecotone is often characterized by a mingling of plant species common to each woodland type, as well as other species that may be specific products of the ecotone itself. Ecotones usually sustain a greater number of plant species than the interfacing woodland types. The diversity of fish and wildlife species sustained by riparian woodlands is in large part dependent upon the structural complexity of ecotones.

Figure 2.12 A common flicker (*Colaptes auratus*) utilizing a cavity within a black cottonwood.

Legislation and the Project Review Process 3

3.1 Introduction

The majority of prospective shoreline construction and maintenance projects will require approvals from regulatory agencies. Federal and provincial agencies, regional districts, and local governments often have jurisdiction over components of proposed shoreline works and, depending on the location and nature of the works, may require a formal application for approval of the works.

This chapter is designed to assist proponents in navigating the project review process by identifying the main agencies involved in the process and discussing their respective mandates. It is a guide and, accordingly, should not be considered a stand-alone reference regarding the regulatory obligations of a project. The regulatory bodies identified can be contacted by proponents for additional advice and guidance.

The primary focus of the chapter is on Fisheries and Oceans Canada as this federal agency has been empowered with the strongest mandate to conserve natural resources within shoreline environments.

3.2 Fisheries and Oceans Canada and the Fisheries Act

The Federal *Constitution Act* (1982) delegates authority for all fisheries in Canada to the federal government. The federal government's responsibilities for fisheries are set out in the Federal *Fisheries Act,* which provides for the management of the fisheries resource and the protection of fish and fish habitats. The *Act* is administered by Fisheries and Oceans Canada (DFO). Key to the project review process for shoreline developments are the habitat protection provisions of the *Act*, which are administered by the Fish Habitat Management Program (www.dfo-mpo.gc.ca/habitat/).

The *Fisheries Act* defines 'fish' to include:

> "fish, shellfish, crustaceans, marine animals", and, "the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals."

Fish habitats are defined in the *Act* as:

> "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes."

Policy level clarification of these definitions is found in the *Habitat Conservation and Protection Guidelines* (1998), which state that:

> "Fish habitat therefore refers to: freshwater, estuarine and marine environments that directly or indirectly support fish stocks or fish populations that sustain, or have the potential to sustain, subsistence, commercial or recreational fishing activities."

Negative impacts on fish and fish habitat associated with shoreline projects and related activities are prevented through the administration and enforcement of the habitat protection provisions of the *Fisheries Act*. Section 35 of the *Act* is a key provision in this regard. Subsection 35(1) prohibits the harmful alteration, disruption or destruction of fish habitat. Subsection 35(2) provides the Minister with the power to authorize terms and conditions that would allow projects to proceed in compliance with the *Act*. Other habitat protection provisions of the *Fisheries Act* include Sections 20, 21, 22, 26, 27, 28, 30, 34, and 37.

3.2.1 National Habitat Policy

The *Policy for the Management of Fish Habitat* (1986, the *Habitat Policy*) provides direction for interpreting the broad powers mandated by the habitat provisions of the *Fisheries Act.* The primary objective of the *Habitat Policy* is to:

> "increase the natural productive capacity of habitats for the nation's fisheries resources, to benefit present and future generations of Canadians."

Productive capacity is defined as:

> "the maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support aquatic organisms upon which fish feed."

Progress toward this objective of a 'net gain' in productive capacity of fish habitat is pursued through the following policy goals of:

- conservation of the productive capacity of fish habitat;
- restoration of damaged fish habitat; and,
- development of fish habitat.

3.2.1.1 Fish Habitat Conservation Goal

The conservation of the current productive capacity of fish habitat is the most important criterion used by DFO when assessing the acceptability of proposed works. Specifically, the goal of conservation, defined in the *Habitat Policy*, is to:

> "maintain the current productive capacity of fish habitats supporting Canada's fisheries resources, such that fish suitable for human consumption may be produced."

When there is a risk of potential damage to habitat, DFO strives to prevent losses of fish habitat.

3.2.1.2 'No Net Loss' Guiding Principle

The guiding principle of the conservation goal of the *Habitat Policy* is to achieve "no net loss of the productive capacity of habitats". In accordance with this principle, DFO strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis.

To ensure 'no net loss', DFO will determine if the proposed works will cause the harmful alteration, disruption or destruction (HADD) of fish habitat, defined as:

> "any change in fish habitat that causes a reduction in the productive capacity of the habitat due to a reduction in its ability to support one or more life processes (e.g. reproduction, feeding, rearing and migration) of fish."

In cases where the productive capacity of fish habitat is high, DFO will typically not authorize a HADD. In those instances where the productive capacity of fish habitat is not high, an authorization of a HADD may be considered by DFO. An authorization may be granted contingent upon the implementation of various measures, including those used to restore or develop fish habitat so that 'no net loss' is achieved.

The application of the 'no net loss' guiding principle in the project review process is outlined by the *Habitat Conservation and Protection Guidelines* (1998).

3.2.2 Project Review Process

Upon submission of an application for approval of shoreline works, DFO will undertake a detailed examination of the potential impacts of the proposed works on fish and fish habitat. The proponent is responsible for providing all appropriate plans, specifications, studies and other information required to allow an assessment of the potential impact of proposed works. Agency personnel will assess the information provided by the proponent and, as required, visit the site and/or request additional studies to be completed by the proponent. The proponent may be required to:

- conduct baseline environmental studies to adequately describe the fish habitat potentially impacted by proposed works;
- develop a habitat mitigation and/or compensation plan to offset impacts to fish habitat, including a monitoring program to confirm fulfillment of the plan's objectives;
- assume the costs of implementing the habitat mitigation and/or compensation plan and the monitoring program; implement corrective measures, as required, to achieve compliance with the habitat mitigation and/or compensation plan;
- participate as required in public information meetings; and,
- ensure that any agreement with DFO regarding fish habitat mitigation and/or compensation does not adversely affect other natural resources.

In determining the severity of potential impacts on fish and fish habitat, the factors considered include:

- the potential for the project to affect fish, fish habitat and/or a particular fishery, as well as the nature of the effect (e.g. physical disturbance, temperature change, flow alteration, release of nutrients or contaminants, reduction in dissolved oxygen, obstruction of fish migration);
- the presence or abundance of a fish species which is actively harvested or has the potential to be harvested in a subsistence, commercial and/or recreational fishery;
- whether the species at risk is considered threatened or endangered;
- the relative productive capacity of the habitat and/or degree to which it supports an important life cycle

process (e.g. spawning, rearing, nursery, overwintering, food supply, migration);
- the availability and anticipated/ proven effectiveness of mitigation and/or compensation measures;
- the relative proportion of available habitat which is affected, both regionally and locally; and,
- the habitat's resilience to damage and the amount of time it would need to recover to full productivity.

Following its examination of the proposed works and the results of any public consultation, DFO will assess whether the project is likely to result in a net loss of habitat. If a loss is likely, DFO will then evaluate the feasibility of proposed impact mitigation and compensation measures.

Depending on the outcome of its assessment, DFO may take one of the following actions:

- allow the project to proceed as proposed;
- allow the project to proceed, but with additional mitigative/ compensative measures following specific authorization from DFO; or,
- disallow the project in cases where the potential loss to fish, fish habitat and/or a fishery is judged to be unacceptable.

3.2.3 Habitat Classification and Levels of Protection

A key element of the project review process is the classification of habitats in terms of the degree to which they contribute to fisheries production. This is to ensure that the level of protection, assessed in terms of the 'no net loss' guiding principle, is appropriate for the habitat under consideration. The *Habitat Conservation and Protection Guidelines* (1998) provides a simplified, three-tier classification approach for defining appropriate levels of protection.

Critical habitats "require a high level of protection because of their importance in sustaining subsistence, commercial or recreational fisheries, their rareness, their high productive capacity, the sensitivity of certain life stages of the fish they support, etc." Harmful alteration, disruption or destruction of critical habitat is typically not authorized.

Important habitats require a moderate level of protection and "may include, for example, areas utilized by fish for feeding, growth and migration, which, while important to the fish stock, are not considered critical. Areas in this category usually contain a relatively large amount of similar habitat that is readily available to the stock. Habitat that has been disrupted by past human activity may also fall into this category." Development that results in the harmful alteration or destruction of important habitats usually can proceed, provided that appropriate mitigation and compensation measures are in place.

Marginal habitats require a minimum level of protection because they "have a low productive capacity and, according to available studies, contribute marginally to fish production, but do have a reasonable potential for enhancement or restoration." Development that results in the harmful alteration or destruction of marginal habitats can proceed, provided that appropriate mitigation and compensation measures are in place.

Management options for project proposals impacting critical, important and marginal habitats, in order of preference, consist of:

- project relocation;
- project redesign;
- mitigation of impacts; and,
- compensation for impacts.

Compensation is the least preferred option and is only accepted when a HADD is authorized by DFO.

3.2.3.1 Fraser River Estuary Shoreline Habitat Classification System

A regionally specific habitat classification system is in effect for the entire Fraser River estuary shoreline. This colour-code based system, developed under the auspices of the Fraser River Estuary Management Program, classifies the overall habitat value of the estuary shoreline and specifies requirements for future human use and development. In highly productive (i.e. critical) habitat areas, development is not permitted unless the proponent can show that no alteration to or alienation of the habitat will occur. In moderately productive (i.e. important) habitat areas, development is permitted subject to satisfactory mitigation and/or compensation actions. In habitat areas of low productivity (i.e. marginal), development is permitted subject to environmentally sound design and timing restrictions.

Habitat areas of high, moderate and low productivity are colour coded red, yellow and green, respectively, on habitat classification maps. Further detail regarding this classification system, and how it is incorporated within the coordinated environmental review process for the Fraser River estuary, may be obtained from www.bieapfremp.org.

3.2.3.2 Courtenay River Estuary Shoreline Habitat Classification System

The Courtenay River Estuary Management Plan borrowed the concept of colour-coded shorelines for its own classification system. The habitat and development classification system utilized for the Courtenay River estuary not only employs a three tiered colour-code based system, it also divides the shoreline into three distinct habitat zones; each zone is afforded its own colour code. The Courtenay River estuary classification system is presented in Figure 3.1. The Plan and classification system are described at www-heb.pac.dfo-mpo.gc.ca/english/cremp/.

3.2.4 Mitigation and Compensation

Projects often require mitigation and/or compensation to maintain the productive capacity of fish habitat. Not all impacts associated with projects, however, can be adequately mitigated or compensated for. In some instances, the impacts are of such a nature and magnitude that significant losses to the productive capacity of fish habitat are inevitable. Such losses are not authorized by DFO.

A detailed inventory of fish habitat in and about the proposed location of works is typically required as a component of the application for works submitted to DFO. This inventory allows DFO to properly evaluate impacts on the productive capacity of fish habitat. The validity of proposed mitigation and compensation measures is evaluated with regard to their ability to achieve DFO's 'no net loss' guiding principle. The inventory documents significant biophysical elements of the location of proposed works, including, but not limited to, topography and bathymetry, substrates, drainage patterns and features, and the species assemblage and areal cover of plant communities.

3.2.4.1 Mitigation

Mitigation is defined as those features of the planning, design, construction and operation of works that minimize or avoid adverse impacts on the productive capacity of fish habitat.

The greatest opportunity to mitigate impacts to fish habitat is during the conceptual design phase of a project. The location and configuration of proposed works can often be manipulated to avoid productive fish habitat.

Construction windows for shoreline development are used as an effective mitigation tool. The construction windows allow in-water works at times when fish are not present and/or sensitive life history stages are not occurring. Examples of sensitive life history stages include downstream migration of juvenile fish, upstream adult spawning migrations, spawning, egg incubation or fry emergence. As the timing of these events varies according to location as well as climatic conditions, local DFO personnel should be consulted regarding construction scheduling.

3.2.4.2 Compensation

Compensation is defined as the modification or creation of fish habitat to offset unmitigable impacts associated with proposed works so as to maintain the overall productive capacity of fish habitat.

DFO has developed a hierarchy of preferences for compensation options. In order of preference, the options are:

- creation of similar habitat at or near the development site and within the same ecological unit (onsite);

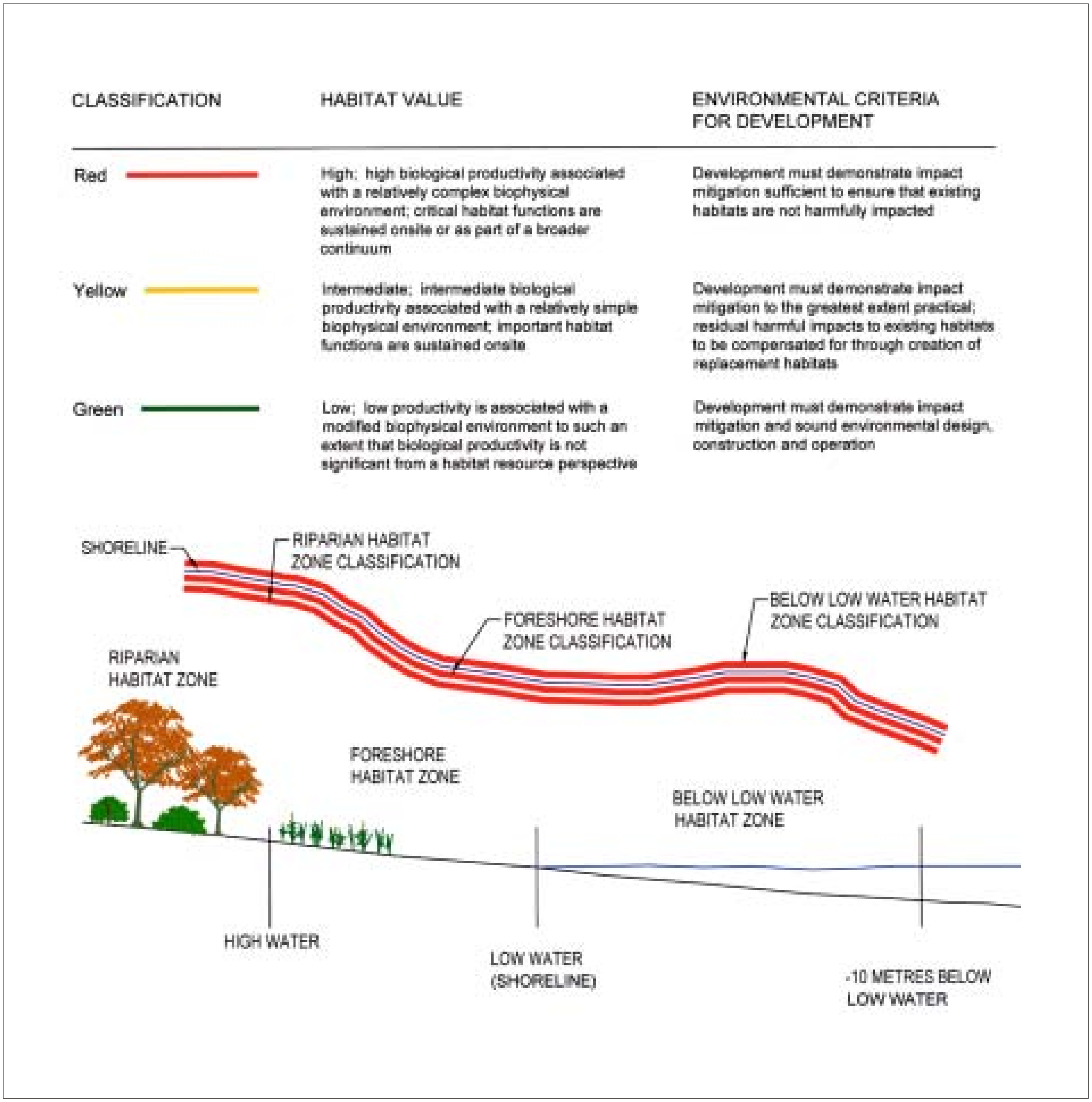


Figure 3.1 Habitat and development shoreline classification system for the Courtenay River estuary.

- increasing the productive capacity of existing habitat at or near the development site and within the same ecological unit (onsite);
- creation of similar habitat in a different ecological unit that supports the same stock or species (offsite);
- increasing the productive capacity of a different ecological unit that supports the same stock or species (offsite); and,
- increasing the productive capacity of existing habitat for a different species of fish either on or off site.

In developing compensation strategies, proponents are obliged to follow the hierarchy of preferences. If a strategy embraces a less preferable option, the proponent must adequately demonstrate, utilizing technical and/or financial criteria, why more preferable options are not feasible.

To determine the extent of compensation required within estuarine and marine environments, DFO personnel often define the quantity of new habitat to be created to offset unmitigable losses of habitat. The quantity of new habitat to be created is dependent upon:

- the productive capacity of impacted and created habitats;
- the interim loss of productivity associated with created habitats achieving full productivity; and,
- the risk of failure associated with the proposed compensation habitat.

3.2.4.3 Habitat Compensation Authorization

When DFO makes a decision to authorize a HADD of fish habitat, a legal Authorization pursuant to Subsection 35(2) of the *Fisheries Act* is issued.

The Authorization includes a description of the works to be undertaken, specifies the period during which the compensation works are to be completed, and summarizes the monitoring program required. The objective of the monitoring program is to assess the efficacy of constructed habitats in achieving compensation habitat design objectives.

3.3 Other Authorities and Acts of Legislation

This section presents agency mandates and legislation, in addition to that of DFO and the *Fisheries Act*, frequently encountered during the project review process for works proposed within shoreline environments.

3.3.1 Federal Agencies

3.3.1.1 Canadian Environmental Assessment Agency

The Federal *Canadian Environmental Assessment Act* (CEAA) was established in 1994 to ensure that environmental effects of federal projects are carefully considered, to promote sustainable development, and to ensure public participation in the environmental assessment process. The CEAA process may be triggered under Section 5 of the *Act* if a federal authority:

- proposes a project;
- grants money to a project;
- grants an interest in land to a project; and/or
- exercises a regulatory duty in relation to a project.

For example, the CEAA process is triggered if DFO authorizes a HADD. The CEAA process includes an environmental assessment, which may range from a screening document for routine proposals to a comprehensive study and panel review for large-scale projects with significant environmental impacts. For most projects, the CEAA process is administered by the regulatory agency that exercises its legislative authority in relation to the project. The regulatory agency administering process is responsible for the decision as to whether or not the project proceeds. The proponent is typically responsible for addressing the information needs of the CEAA regulatory agency.

The CEAA process was harmonized with the Provincial *Environmental Assessment Act* project review process through the "1997 Canada-British Columbia Agreement for Environmental Assessment Cooperation". The agreement was applied to projects subject to environmental legislation of both governments. The agreement expired in 2002. The Federal *An Act to Amend the Canadian Environmental Assessment Act* is currently being reviewed by the federal government. The *Environmental Assessment Act* has recently been amended by the provincial government. As a result, the federal and provincial governments have proposed to amend and extend the 1997 agreement on an interim basis until a new long term agreement can be negotiated based on the new legislation of both governments. Updates and further information on harmonization of federal and provincial environmental review processes may be obtained from www.ceaa-acee.gc.ca.

3.3.1.2 Canadian Coast Guard, Fisheries and Oceans Canada

The Canadian Coast Guard administers the Federal *Navigable Waters Protection Act* (NWPA). Section 5 of the *Act* regulates any activity that could impact navigable waters. Navigable waters include:

- "any body of water capable, in its natural state, of being navigated by floating vessels of any description for the purpose of transportation, recreation or commerce";
- "a canal and any other body of water created or altered for public use"; and
- "any waterway where the public right of navigation exists by dedication of the waterway for public purposes, or by the public having acquired the right to navigate through long use".

Approval for any project within navigable waters must be obtained from the Navigable Waters Protection Division of the Canadian Coast Guard (www.pacific.ccg-gcc.gc.ca/nwp/).

Sections of the NWPA are included on the Law List of the Federal *Canadian Environmental Assessment Act* and, with their application to a project, may trigger a CEAA environmental assessment.

3.3.1.3 Port Authorities

Ports and harbours are a common feature of coastal British Columbia; many of these facilities are managed by Port Authorities. Port Authorities are governed by the Federal *Canada Marine Act*, which replaced the Federal *Canada Port Corporation Act*, *Harbour Commissions Act* and *Public Ports and Harbour Facilities Act*. Part 1 of the *Act* provides for the establishment of 18 Canada Port Authorities including: Fraser River Port Authority; Nanaimo Port Authority; North Fraser Port Authority; Port Alberni Port Authority; Prince Rupert Port Authority; and, Vancouver Port Authority. These Authorities have broad powers of administration over land and water in their jurisdictions, including management of federal real property, issuance of leases and licences, land use planning and establishment of bylaws. Part 2 of the *Act* also provides for the establishment of public port authorities for those ports and harbours not designated as Canada Port Authorities. Proposed works in port jurisdictions are not to compromise the integrity and efficiency of the port or harbour system and the deployment of resources. Approval must be obtained from the local authority prior to any works being carried out within the respective port.

Regulations made under the Federal *Canadian Environmental Assessment Act* stipulate how environmental assessments are to be conducted by Canada Port Authorities (www3.ec.gc.ca/EnviroRegs/). These regulations define the environmental assessment process to be followed for specific types of projects. Port Authorities conduct environmental assessments as part of the overall administration of proposed land and water uses within their jurisdictions.

3.3.1.4 Environment Canada

The estuaries of coastal British Columbia provide critical staging and breeding habitat for migratory shorebirds and waterfowl. The Canadian Wildlife Service (CWS) of Environment Canada manages migratory bird habitat through authority provided by the Federal *Migratory Birds Convention Act* (www.pyr.ec.gc.ca).

The Migratory Birds Regulations and the Migratory Bird Sanctuary Regulations are enabled by the *Migratory Birds Convention Act.* These regulations, respectively, address the protection of migratory birds and migratory bird sanctuaries. Sections of both regulations are included in the Law List of the Federal *Canadian Environmental Assessment Act* and, accordingly, may trigger a CEAA environmental assessment.

The Environmental Protection Branch of Environment Canada is responsible for administering the Federal *Canadian Environmental Protection Act*, the Federal *Canadian Environmental Assessment Act* and Section 36 of the Federal *Fisheries Act*. Section 36 prohibits the deposit of deleterious substances in waters frequented by fish unless authorized by regulation under the *Fisheries Act*. Environment Canada's responsibilities for Section 36 are derived from a Memorandum of Understanding with DFO. The Minister of Fisheries and Oceans Canada, however, remains accountable to Parliament for all components of the *Fisheries Act*.

3.3.2 Provincial Government Agencies

3.3.2.1 Ministry of Water, Land and Air Protection

The Environmental Stewardship Division of the Ministry of Water, Land and Air Protection (MWLAP) recommends standards and best practices for works and related activities within shoreline environments. These recommendations are considered as: terms and conditions provided by a Habitat Officer pursuant to Sections 40 and 42 of Part 7 of the Provincial *Water Act* Regulation for a Notification pursuant to Section 44; and, advice for applications pursuant to Section 9 of the Provincial *Water Act*. Application and reporting standards are provided by MWLAP. The information provided by applications and reports is utilized by the Environmental Stewardship Division to maintain and restore fish and wildlife species and their habitats.

The Inspector of Dikes Office, Public Safety Section, is responsible for administering the Provincial *Dike Maintenance Act*, which provides the legislative basis for the operation and maintenance of public dikes in British Columbia. The Inspector of Dikes Office is responsible for the approval of all works in and about dikes, joint inspections with local authorities to monitor and audit dike management programs, and the issuance of orders to protect public safety.

The Environmental Protection Division of MWLAP is responsible for administering the Provincial *Waste Management Act*, which regulates the discharge of solid waste, effluent and emissions into the environment. Wastes may only be discharged in accordance with permits or approvals issued by MWLAP, a Liquid Waste Management Plan or the *Municipal Sewage Regulation* of the *Act*. Part 4 of the *Act*, "Contaminated Site Remediation", sets out rules for the identification, remediation and liability associated with contaminated sites. A number of conditions can trigger the initial 'site profile' requirements under this section, such as subdivision, rezoning, or development permit applications for land that the applicant "knows or reasonably should know is or was used for industrial or commercial activity."

Further information regarding the mandate and management activities of MWLAP may be obtained at www.gov.bc.ca/wlap/.

3.3.2.2 Ministry of Sustainable Resource Management

Low lying coastal areas were the preferred locations for settlements of both First Nations peoples and early European settlers. Today, many of these areas sustain relics of these settlements that are of archaeological and/or historical significance. The Archaeology and Forests Branch of the Ministry of Sustainable Resource Management (MSRM), under the legislative authority of the Provincial *Heritage Conservation Act*, reviews applications for works that may impact sites that are of archaeological and/or historical significance. In those instances where proposed development may damage archaeological sites protected under the *Act*, the Branch will advise the applicant that an archaeological impact assessment is required. A decision or recommendation regarding proposed development is dependent upon the findings of the impact assessment. Further information regarding the project review process as administered by the Archaeology and Forests Branch may be obtained at www.archaeology.gov.bc.ca.

The Ministry administrates the activities of independent government bodies that may facilitate and/or participate in the review and/or approval of proposed uses within shoreline environments. Three of the more relevant of these bodies include:

- Land and Water British Columbia Inc.;
- Environmental Assessment Office; and,
- Land Reserve Commission.

Land and Water British Columbia Inc.

The Water Management Branch of Land and Water British Columbia Inc. is responsible for enforcing the provisions of the Provincial *Water Act* (www.bc-land-assets.com/water/). Provisions within this piece of legislation pertain to any activities that could affect either the volume of water flowing in a watercourse (i.e. Section 8, "short term use of water") or the morphology of the channel of the watercourse (i.e. Section 9, "changes in and about a stream"). An approval or license must be obtained from the Comptroller of Water Rights for works that may affect the flow of water and/or the physical environment of a watercourse.

Environmental Assessment Office

The Environmental Assessment Office (EAO) administers the Provincial *Environmental Assessment Act* (www.eao.gov.bc.ca). The *Act* provides a single review process to assess certain major projects and activities in British Columbia. The review takes into account a broad range of effects for all reviewable projects. Those effects assessed are categorized as environmental, economic, social, health, cultural and heritage.

The *Act* addresses reviewable projects as designated by regulation, the Executive Director of the EAO, or the Minister of Sustainable Resource Management. Reviewable project categories are industrial, energy, mining, water, waste, food processing, transportation and tourism. An environmental assessment certificate is granted a reviewable project upon acceptance of potential effects identified by the assessment and conditions thereof, as required, that reduce the severity of such effects.

Constitutional responsibility for management of the environment is shared between the federal and provincial governments. As a result, projects subject to the Provincial *Environmental Assessment Act* may be subject to the Federal *Canadian Environmental Assessment Act*. Currently, a draft amendment to the "1997 Canada-British Columbia Agreement for Environmental Assessment Cooperation", as presented in Section 3.3.1.1, proposes that, for all reviewable projects, federal agencies will designate the process of screening or comprehensive study under federal legislation to the provincial EAO. Each government retains autonomy over their respective decisions regarding approval of the project; each government retains its decision-making role. The decisions are made on the basis of shared information and are analyzed through a single process facilitated by the EAO.

Land Reserve Commission

Dikes are often constructed to prevent the flooding of agricultural lands. Many such dikes are constructed on lands within the provincial Agricultural Land Reserve (ALR). Proposed works that could affect agricultural lands within the ALR require approval from the Land Reserve Commission. In part, the Land Reserve Commission governs uses and activities on ALR lands. The Commission is granted its authority to govern such uses and activities by the Provincial *Land Reserve Commission Act*, *Agricultural Land Commission Act*, and *Soil Conservation Act* (apps.icompasscanada.com/lrc/).

3.3.3 Municipalities and Regional Districts

In urbanized areas, Municipalities and Regional Districts, as mandated under the Provincial *Local Government Act*, conduct project reviews to assess compliance with municipal zoning bylaws. Proposals for the maintenance or repair of existing facilities often fall under the jurisdiction of municipalities.

Municipalities and Regional Districts formulate Official Community Plans to set out land use zoning and other development requirements. For shoreline developments, leave strips may be required, the width of which are dependent on the environmental sensitivity of the area. Neighbourhood Community Plans further define land use zoning and other development requirements for specific areas within the municipality.

Many local governments have undertaken planning exercises that define Environmentally Sensitive Areas (ESA's) or classify streams and/or shorelines according to fish and wildlife habitat value. The ESA's and classifications are typically incorporated within the Official Community Plan.

The detailed review of development proposals and related activities (e.g. municipal infrastructure improvements) often includes an assessment of environmental impacts. A dialogue with DFO, regarding issues pertaining to fish and fish habitat, is maintained through an Environmental Review Committee facilitated by the Planning or Engineering Departments of the respective Municipality. Recommendations provided by DFO are incorporated within the response from the Municipality to the proponent of development. Subsection 35(2) Authorizations, as required, are often included as a condition of approval from the Municipality.

The Provincial *Drainage, Ditch and Dike Act* and *Local Government Act* provide local governments with the authority to undertake diking and drainage through local bylaws and Improvement Districts. Responsibility for the operation and maintenance of dikes constructed by local diking authorities, diking districts and municipalities is vested with these organizations. However, supervision and approval of all works associated with public dikes is the responsibility of the provincial Inspector of Dikes Office.

Facilities and Structures 4

4.1 Introduction

Structures and facilities such as bridges, wharves and marinas are prevalent within developed shoreline environments. In the past, these features were designed with little consideration of their impacts upon fish and wildlife habitats. The design process has evolved to where environmental design criteria are now a primary consideration. This evolution has been facilitated by environmental agencies through the various project review processes administered within coastal British Columbia.

This chapter consolidates state-of-the-art environmental design criteria that are frequently applied on a project-by-project basis. The feasibility of development proposals, in terms of fish and wildlife habitat conservation, is contingent upon the incorporation of such criteria within the overall project design. The chapter specifically addresses design elements such as size, footprint, materials, location and surface texture, all of which can be modified to reduce the impacts of structures and facilities on shoreline environments.

Although design issues pertaining to the mitigation of impacts on the nearshore subtidal environment are addressed, the focus of the chapter is primarily on the foreshore environment. Furthermore, environmental design criteria for dikes are presented in Chapter 6, as dikes possess some unique design issues that are more appropriately considered in a separate context.

4.2 Description of Structures

4.2.1 Types of Structures

Foreshore structures may be grouped into one of two categories, those that are supported or anchored by piles, and those that incorporate fills, revetments and slabs.

Pile supported and anchored structures include:

- bridges (Figure 4.1) and piers;
- docks, floats (Figure 4.2) and buoys;
- log booms (Figure 4.3); and
- timber walkways.

Fill, revetment and slab structures include:

- bridge and pier abutments (Figure 4.4) and footings;
- wharves (Figure 4.5) and other bulkheads;
- access ramps and spillways;
- dikes, training walls (Figure 4.6), breakwaters and groynes; and
- utilities such as pipelines and cables, pump stations and floodboxes, and sewer outfalls.

The footprints associated with facilities and structures within these two categories differ significantly. The footprint is defined as that area of habitat that is either removed or covered by the structure. The definition does not include that area that is shaded by the structure. Typically, pile supported and anchored structures minimize the footprint on foreshore and nearshore subtidal environments. In contrast, fill, revetment and slab structures are characterized by relatively large footprints (Figures 4.7 and 4.8).

4.2.2 Conventional Material Types

Shoreline structures may be constructed of wood, rip rap, concrete and/or steel.

4.2.2.1 Pile Supported and Anchored Structures

The use of wood as a construction material includes the use of wood preservatives. Wood preservatives significantly extend the life of wood structures. Their effectiveness lies with their toxicity to organisms that would otherwise bore into and/or consume the wood, eventually compromising the integrity of the structure.

Historically, many pile-supported structures were constructed almost entirely of wood. The

Figure 4.1 Arterial road bridge, Middle Arm distributary channel, Fraser River.

Figure 4.2 Marina floats, Deas Slough, Main Arm distributary channel, Fraser River.

Figure 4.3 Log booms at Timberland Basin, Annieville Channel, Fraser River.

Figure 4.4 Pier abutment, Annieville Channel, Fraser River (inset: abutment during construction)

Figure 4.5 Wharves, Annieville Channel, Fraser River.

Figure 4.6 Steveston Jetty, delta front at Sturgeon Bank, Fraser River.

wood, both timbers and piles, was treated with creosote. Although still required by some construction standards (e.g. 1988 Bridge Code (CAN/CSA S6-88)), recent use of creosote treated timbers and piles has been primarily within high salinity brackish and salt water environments, where it is the wood preservative that is most effective in deterring marine borer activity.

Chromated copper arsenate (CCA) treated timbers are often used for the decking and superstructures of piers, wharves and light duty structures such as pedestrian boardwalks and viewing platforms. CCA treated piles may be used for light duty structures where the bearing load is small and only a shallow foundation depth is required.

Douglas fir, which is structurally stronger than hemlock and ponderosa pine, is the preferred species for construction of wood structures. Douglas fir, however, is not effectively treated by CCA. Ammoniacal copper zinc arsenate (ACZA) is more effective than CCA in the treatment of Douglas fir. New construction of

Figure 4.7 Slab (access ramp) and pile supported (pier) structures, North Arm distributary channel, Fraser River.

The difference in the areal extent of the footprints of a typical pile supported structure and a slab structure is readily apparent. The pile-supported structure accommodates a highly productive inter-tidal fresh marsh. In contrast, the slab is marginal habitat for fish and wildlife.

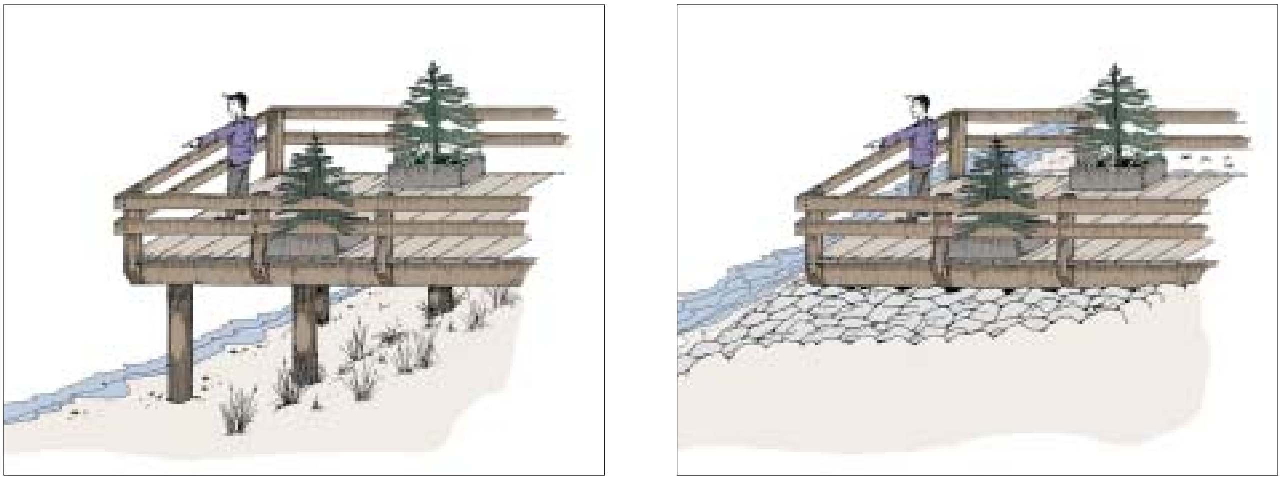


Figure 4.8 The use of piles (left) rather than fill (right) can significantly reduce the footprint of a structure while retaining the same usable area.

wood structures typically utilizes timbers and piles treated with ACZA.

Concrete and steel are often used for heavy-duty structures. The use of steel for structures is often preferred by design engineers and constructors as it is amenable to modification during or after installation. For example, if a pile is driven too deep, whereby the top of the pile is below design elevation, it is far easier to fix an extension to a steel pile (welded steel) than to a concrete pile (formed concrete with rebar connection).

4.2.2.2 Fill, Revetment and Slab Structures

Wood is the least utilized material type for fill, revetment and slab structures. Its use is primarily as a revetment for small-scale bulkheads and as the superstructure and foundation for small floodboxes and pump stations. Historically, creosote treated wood was used extensively for such structures. The use of creosote treated wood, as for pile supported and anchored structures, now occurs primarily within high salinity brackish and salt water environments. For low salinity brackish and fresh water environments, the use of ACZA treated wood is now the construction standard.

Rip rap is generally used for erosion protection, and is the primary material used for the construction of training walls, breakwaters, and groynes. As erosion protection, it is used to armour the lower banks of dikes and natural shorelines, and the margins of pier foundations, bridge abutments, and other concrete works that may be exposed to excessive fetch, wake and currents.

Steel sheet pile is used to retain structural fills associated with wharves and other bulkheads. It is often used within marina basins to stabilize banks cut and exposed during dredging.

Concrete is the primary construction material for free standing and foundation structures. These include bridge abutments, columns and column footings, foundations and casings for pipelines, cables and storm sewer outfalls, and the lower superstructures and foundations of pump stations and floodboxes. Prefabricated concrete structures, such as lock-blocks, are used to contain fill.

4.3 Environmental Design Parameters

There are several design elements that can be modified to reduce the impact of structures.

These include:

- size and footprint;
- materials;
- location; and
- roughness.

4.3.1 Pile Supported and Anchored Structures

4.3.1.1 Size and Footprint

Size relates to the usable area of a structure. For pile supported and anchored structures, size determines the area shaded by the structure. An increase in size decreases the intensity of light and increases the area shaded (Figure 4.9).

Shading can have a significant impact on the vigour of intertidal marsh and nearshore subtidal submergent plants such as eelgrass and kelp. The impact on plants can be either chronic or acute. Chronic impacts are those that do not eliminate plants entirely from the shaded area. Such impacts include reduced areal cover, vegetative production and/or seed production. Acute impacts are those that eliminate existing plants entirely, leaving affected areas barren.

For both fixed and floating structures, the extent and intensity of shading may be minimized by incorporating perforations or large spaces within the decking (Figure 4.10). Light penetration may be achieved simply through incorporating larger spacings between deck planks, or utilizing an alternative deck surface, such as metal mesh. Such design considerations must, however, acknowledge the designed use for the deck area. The greatest potential for user conflict is associated with structures that are to be used extensively by pedestrians.

Fixed structures such as bridges, piers and walkways should incorporate features that increase the diffusion of light upon underlying habitats. For all fixed structures, this can be achieved by increasing the height of the structure above affected habitats (Figures 4.11 and 4.12). For bridges, a further increase in the diffusion of light to areas beneath the structure can be achieved by splitting the deck (i.e. lanes) of the bridge.

For piers, diffusion may be increased by reducing the size of the structure without compromising its designed use. For example, the conventional design for a pier incorporates a deck with a long rectangular configuration, of constant width, that accommodates both cargo handling and interim storage. In most instances, loading and unloading of cargo is restricted to the most offshore portion of the pier; the nearshore portion of the pier is essentially a corridor utilized for the transport of cargo. As a result, the design width requirement for the nearshore portion of the pier deck is less than that for the most offshore portion. Accordingly, the width of the nearshore portion may be reduced without compromising the intended use of the pier (Figure 4.13).

Figure 4.9 The intensity of light is increased beneath a pile structure by incorporating several smaller decks in place of one large deck to achieve design use objectives (adapted from Witherspoon & Rawlings 1994).

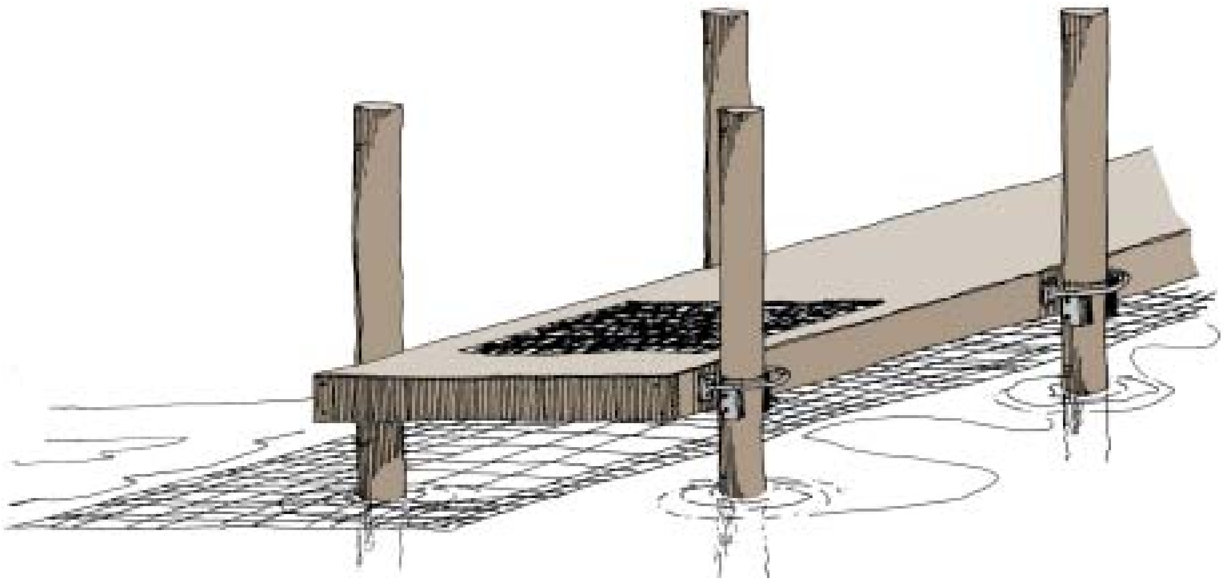


Figure 4.10 Grating incorporated as part of the decking of structures can significantly decrease the extent of shading (adapted from Witherspoon and Rawlings 1994).

Floating docks are designed for installation within nearshore subtidal environments and are typically less than 4 metres in width. The impact of floating docks on the submergent plant community is dependent on the depth of water beneath the structure. The shallower the water at low tide, the greater the potential for impact; accordingly, the width of the dock should decrease with decreasing depth. In general, the width of the dock should not exceed the depth of water. For example, at 3 metres depth, the dock width should not exceed 3 metres.

4.3.1.2 Materials

New construction of wood structures within shoreline environments utilizes timbers and

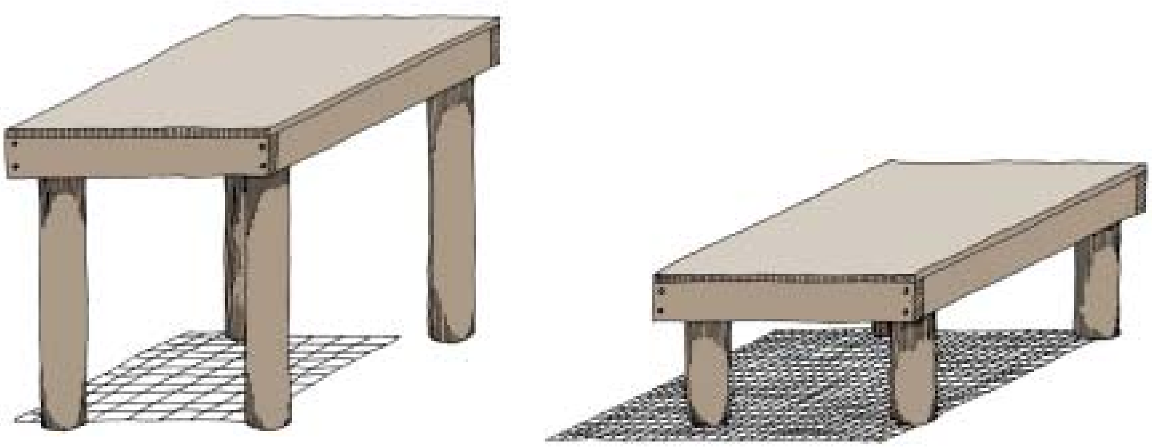


Figure 4.11 The intensity of light is increased and the area shaded is decreased by increasing the height of the pile structure (adapted from Witherspoon and Rawlings 1994).

Figure 4.12 Pile supported and anchored structure, Chatham Reach, Pitt River.

Floating docks are linked to upland by a pedestrian pier that spans approximately 125 linear metres of intertidal fresh marsh and mudflat. The floating docks do not ground at low tide. The pier is high, narrow and is aligned in an east-west direction. These design features minimize both the intensity and areal extent of shading of the marsh.

piles treated with preservatives. Although they extend the life of structures, preservatives leach from treated wood, and as such, pose a threat to aquatic life residing in proximity to the wooden structure.

To mitigate impacts of treated wood upon aquatic life, projects must use wood products treated to Best Management Practices (BMP) standards (Canadian Institute of Treated Wood and Western Wood Preservers Institute 1997). BMPs for the in-plant preservation of wood have been recognized by Environment Canada and Fisheries and Oceans Canada as a useful tool for agency staff, with the provisos that the BMPs must be updated as knowledge improves, and that even wood treated according to BMPs can have impacts on aquatic life under certain conditions (Hutton and Samis 2000). The BMP mark (Figure 4.14), a legal trademark in the United States but without such status in Canada, is used in British Columbia by the Canadian Softwood Inspection Agency to certify wood products treated with preservatives according to BMPs.

In addition to being treated to BMPs standards, creosote treated wood should be aged at least three months prior to in-water installation. Aging allows some of the volatile components to evaporate, considerably reducing the surface sheen often associated with creosote treated wood installed within water. Effective evaporation is contingent upon the free movement of air surrounding treated timbers and piles. Facilities storing treated wood must have a contained drainage system whereby runoff from the surface of aging wood does not drain into a water body sustaining aquatic life.

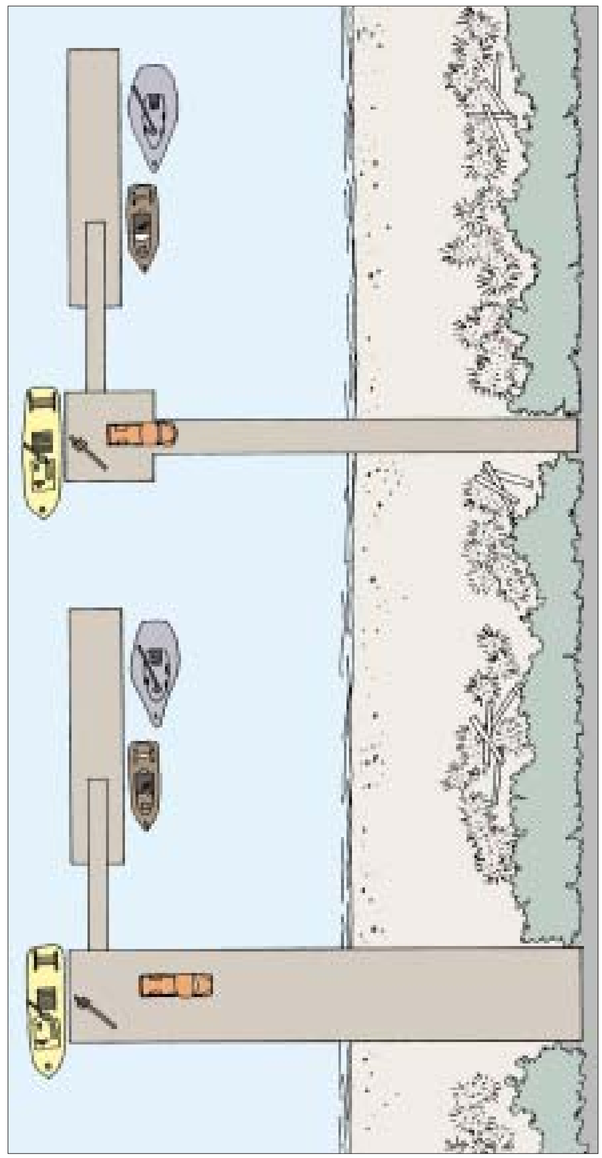


Figure 4.13 A reduction in the shoreward portion of a pier (top) increases the intensity of light and reduces the area shaded; the intended use of the pier is easily maintained.

Figure 4.14 BMP mark.

The design of the wooden structure can incorporate features that minimize leaching of creosote from treated wood. Creosote is mobilized and leached from treated wood under intense solar radiation. The design of the structure must consider the extent of exposure of treated wood to direct sunlight; the most susceptible portions of a structure are those that are infrequently or never submerged. The leaching of creosote from emergent structures can be minimized by incorporating design features that enhance shading (e.g. overhanging decks). Where adequate shading cannot be achieved, the design must pursue an alternative construction material, such as ACZA treated wood, concrete or steel.

Leachable toxins associated with CCA and ACZA treated wood include copper, arsenate, zinc and chromate. Of these toxins, copper poses the greatest risk to aquatic life. When an alternative to CCA-treated wood is not available for use, the wood must be treated with CCA-C. CCA-C is the most leach resistant of three formulations of CCA available for use.

Although CCA-C is the most leach resistant of the three formulations of CCA, wood treated with this preservative should be substituted with wood treated with ACZA when possible. ACZA is more leach resistant than CCA-C.

In order to mitigate the impact of the use of treated wood as a construction material within shoreline environments, an integrated approach of material substitution and restricted use is required (Figure 4.15). Piles, bulkheads and bridges are ideal candidates for material substitution. These structures can be feasibly constructed of either concrete or steel. For example, steel is quickly replacing treated wood as the material of choice for piles in many structures. Recent decreases in the cost of steel, and the longer life of steel relative to treated wood, provide an extremely cost effective material alternative for many long tenured structures.

The decks of floating docks are typically constructed of either CCA or ACZA treated timbers. Material alternatives are available; however, for small to medium scale projects, treated wood is currently the most practical construction material. Concrete has been used for the decks of large docks; these are rather elaborate structures that integrate the deck with concrete floats.

Dock design should not use styrofoam blocks for floatation. Styrofoam readily breaks apart; pieces may be ingested by animals, in particular birds. High-density foam is an acceptable construction material for floats. It is both environmentally benign and very cost effective.

A considerable volume of wood preservative is delivered to shoreline environments by treated-wood splinters generated by the rubbing of floating docks, booms and boats against treated piles. Bumper timbers and piles should be protected with high-density polyethylene wear strips.

4.3.1.3 Location

In all instances, structures should span the foreshore zone. The structure should not significantly modify the prevailing physical processes where such modification would compromise physical fish and wildlife habitat features. For example, training walls and jetties in estuaries must be assessed with regard to their prospective impact on salinity and sedimentation regimes. In the past, such

Figure 4.15 Viewing platform, Burnaby Foreshore Park, North Arm distributary channel, Fraser River.

The platform design, through incorporation of steel and concrete as its primary construction materials, mitigates the impact of material types on the shoreline environment.

structures have caused changes in areal cover and plant species composition of foreshore marshes, changes in areal cover of nearshore subtidal eelgrass meadows, and changes in the sediment budget of foreshore and nearshore subtidal mudflats.

The areal extent and intensity of shading on foreshore and nearshore subtidal environments must be minimized by the design of the structure, especially where the structure spans marsh, eelgrass meadows and beds of macroalgae. To adequately mitigate the impact of shading, the design must consider the orientation of the structure to the shoreline relative to the position of the sun in the sky (Figure 4.16). For example, structures that have a southern aspect typically cause significantly less shading of the foreshore and nearshore subtidal environments than similar structures that have a northern aspect. Depending on the orientation of the shoreline to the position of the sun, structures may be aligned at an angle to the shoreline to minimize shading. Careful analysis of the prevailing light regime will dictate the appropriate alignment of the structure.

4.3.1.4 Roughness

Roughness refers to the texture of the material utilized for construction. In general, the greater the roughness, the greater the diversity of microhabitats for aquatic organisms. Rough surfaces trap organic material that in turn is both habitat and food for a myriad of aquatic invertebrates. Rough surfaces within salt water environments also provide points of attachment for encrusting organisms, such as macroalgae, mussels and barnacles.

Concrete piles possess coarse surfaces that allow the ready attachment of encrusting organisms within high salinity brackish and salt water environments. In contrast, steel piles possess a smooth surface that deters the establishment of a vigorous encrusting community. Although treated wood piles possess a rough surface texture that would normally permit the attachment of encrusting organisms, the

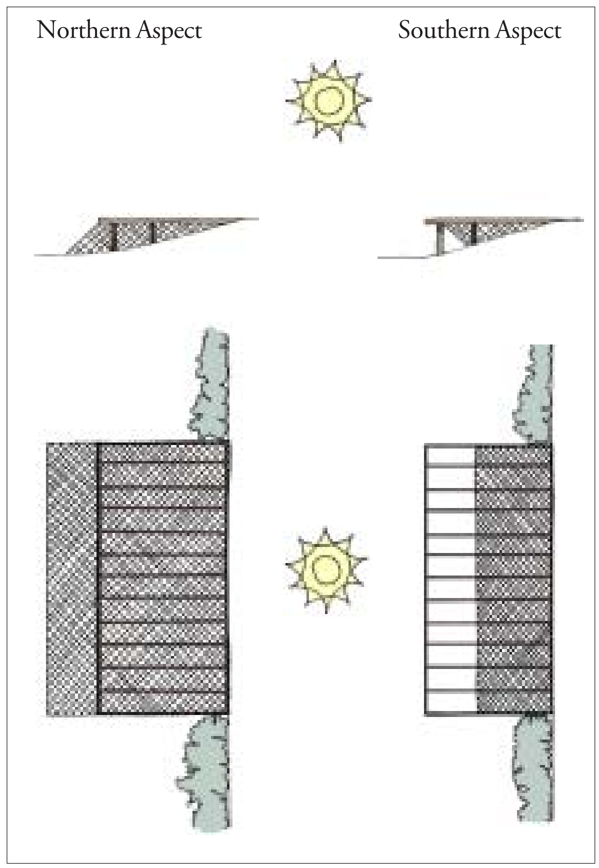


Figure 4.16 Relationship between shading and aspect of structures.

preservatives, especially with new piles, deter colonization of the pile surface.

Concrete floats, in contrast to concrete piles, typically have a finished surface that is smooth. Steel drum floats have a surface texture that is similar to that of steel piles. In high salinity brackish and salt water environments, increasing the surface roughness of floats is not a practical consideration, as encrusting communities can substantially increase the weight of docks, thereby compromising the buoyancy of the entire dock structure.

Increasing the surface roughness of piles for the purpose of increasing local productivity is best achieved within high salinity brackish and salt water environments. Furthermore, the potential for enhancing the encrusting community at a particular location is greatest for support piles. Anchor piles, which tether docks and other floating structures that move up and down with fluctuating water levels, require a relatively clean surface to ensure the unhindered movement of structures.

4.3.2 Fill, Revetment and Slab Structures

4.3.2.1 Size and Footprint

The footprint of fill, revetment and slab structures can be significant. The footprint is directly related to the size of the structure. This relationship is in marked contrast to pile supported and anchored structures where the footprint is typically small and is not necessarily a direct function of the size of the structure.

Size reduction is typically the first design consideration for mitigating the impact of these types of structures. Design alternatives that can achieve a reduced footprint are those that incorporate piles or other reduced footings to support the structure. Interestingly, recent upgrades to seismic construction standards have required that piles be incorporated as part of the overall design to increase the stability of the structure in the event of an earthquake. Such is the case with bridge abutments; fill pads are now being replaced by pile-based foundations. In the instance of foundation fills and concrete structures, due consideration must be afforded to design alternatives that incorporate piles and other reduced footings to decrease the footprint of the structure.

4.3.2.2 Materials

Consideration of material alternatives for fill, revetment and slab structures is dependent upon design alternatives that can incorporate other material types. Rip rap revetments may be replaced by steel sheet pile to significantly decrease the footprint of the revetment. The cost of a steel sheet pile structure, however, is substantially greater than that of a rip rap structure. As a result, for small revetment projects, the cost effectiveness of rip rap may preclude the use of steel sheet pile.

For breakwaters, the feasibility of design alternatives will partially depend on the prevailing energy regime of the site affected by proposed works. A floating breakwater, constructed of floating materials such as logs, barges or concrete pontoons, can be cost effective for partially protected sites where the wave heights to be dissipated are modest. A floating breakwater has a substantially smaller footprint than a rip rap breakwater. A reduction in footprint can also be achieved through breakwater design that incorporates a vertical wall constructed of a single row of piles. Where timber piles are considered, however, they would likely be treated and therefore would introduce wood preservatives into the aquatic environment. Introducing toxins into the aquatic environment is strongly discouraged. Care must always be taken not to substitute one undesirable design option with another.

4.3.2.3 Location

The most effective impact mitigation for fill, revetment and slab structures is to locate these structures outside of foreshore and nearshore subtidal environments. The consideration of such designs must also include potential impacts on fish and wildlife resources both offshore and landward of these environments. In all instances, the design of a structure must seek to minimize the use of fill, revetment and slab design components.

Where design constraints demand the location of a slab structure be within the foreshore or nearshore subtidal environment, such as a boat ramp, the design of the structure must consider impacts to physical processes typically associated with shorelines. The structure must achieve a design that does not significantly alter the prevailing current, wave and drift regimes. Structures have the potential to alter rates of flushing, material accretion, erosion and other processes. Such changes to physical processes can impact both onsite and offsite fish and wildlife habitats.

4.3.2.4 Roughness

Increasing the roughness of fill, revetment and slab structures has its greatest benefits within high salinity brackish and salt water habitats. Fill structures constructed of rip rap, such as breakwaters, are in essence an artificial reef. They provide similar structural habitat features to those present in natural reefs. Notwithstanding engineering considerations, the size of rock used for breakwaters can be modified to benefit target species. The larger the diameter of the rock, the larger the voids within the structure. Larger voids provide refugia for larger reef inhabitants, such as lingcod, while smaller voids provide refugia for smaller reef inhabitants, such as coonstripe shrimp.

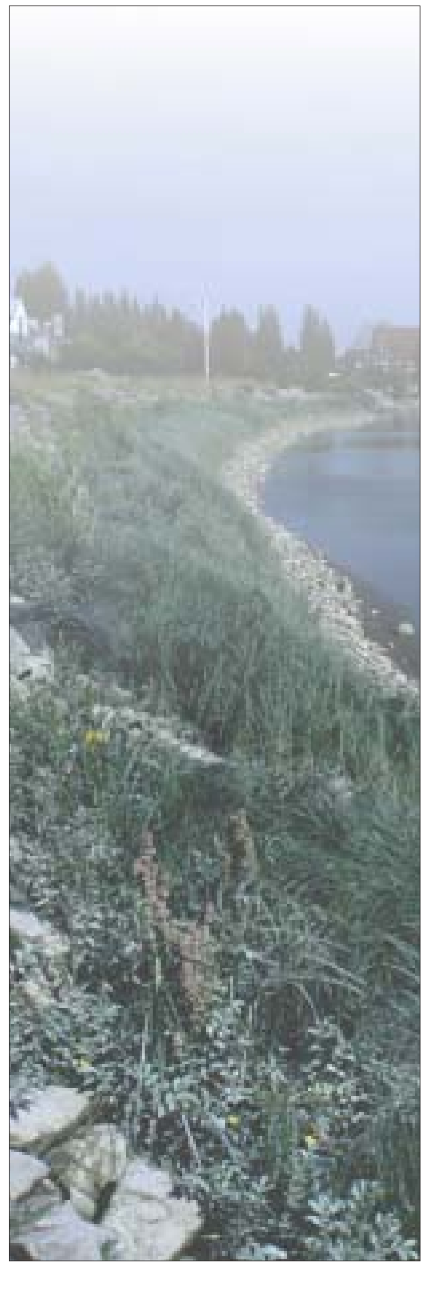
Concrete slab structures within high salinity brackish and salt water environments can be modified to enhance their ability to sustain productive encrusting communities. The vertical sides of slabs are typically flat. They deflect wave energy in several directions without significantly reducing it. The energy of the waves, and the log debris that often occurs within coastal environments, scour the face of these structures, significantly reducing the vigour of encrusting communities. Incorporating recesses in the vertical face of slab structures provides encrusting organisms with habitat adequately protected from excessive scour.

For all salinity regimes, rip rap revetments can be modified to sustain a variety of productive habitat features. Benches are one of the most effective of these features. They are a structural extension of the revetment. The surface elevation of the bench is dependent on the habitat type to be created. High elevation benches, typically above the mean high water mark, are created to sustain a community of shrubs and small trees. Mid elevation benches, located at elevations between the mean high and low water marks, are created to sustain intertidal communities ranging from gravel/cobble beds of macroalgae to stands of marsh vegetation (Figure 4.17). Low elevation benches, from mean low water to several metres below lowest low water, are created to sustain beds of submergent vegetation. For mid-to-low elevation benches, careful consideration must be afforded to the prevailing energy regime and the potential for log debris accumulation; high energy and debris accumulation can significantly hamper the productivity of habitat benches. With careful design consideration, rip rap benches can significantly enhance the functional value of revetments to fish and wildlife. Chapter 5 provides further detail regarding the design of benches.

Figure 4.17 Marsh bench within rip rap revetment shortly after planting, Ladner Reach, Fraser River.

Dikes 5

5.1 Introduction



Dikes are inherently located within the transition zone of aquatic and terrestrial environments. This zone sustains some of the most productive fish and wildlife habitats in British Columbia. As dikes are often many kilometres long, they can have a profound impact on the functional capacity of these habitats to support fish and wildlife, as is evident in the legacy of largely irreversible habitat losses attributable to major diking initiatives of the past. Such initiatives were focused strictly on land reclamation and did not consider impacts on fish and wildlife habitats.

While the era of large-scale dike construction is over, fish and wildlife habitat conservation remains a critical issue in the development of new dikes, modification of existing structures, and dike maintenance. Habitat conservation can be achieved with the application of an integrated and interdisciplinary design approach that accounts for prospective impacts to fish and wildlife habitats and incorporates features that mitigate such impacts to the fullest extent practical. In this regard, some progress has occurred over the past two decades through the collaborative efforts of environmental and diking agencies. However, many dike design criteria and maintenance protocols continue to emphasize sterile, minimally vegetated structures that contribute little to the goal of habitat conservation.

Chapter 5 provides environmental design criteria for dike construction and maintenance initiatives, with a clear focus on the consideration of approaches and features compatible with the primary function of diking, that of flood protection. Conventional structural design criteria essential for flood protection are discussed, followed by the presentation of innovative environmental design criteria regarding the location and alignment of dikes, the establishment of vegetation features, and dike maintenance.

5.2 Structural Design

Traditional dike design considerations include:

- flow, tide and wave regimes;
- channel shape and configuration;
- available construction materials such as appropriate fill and rip rap;
- bank conditions at the site, prior to construction;
- space limitations; and
- upland uses.

Dikes are designed and constructed to prevent flooding of low lying lands during flood events. Dikes can be damaged by currents, waves and flooding. Accordingly, an important component of dike design is the maintenance of the integrity of the dike. Generally, the structural elements of dikes include:

- a dike shoulder set at an adequate elevation to prevent overtopping during a design flood event;
- gentle grades on both the waterside and landside slopes; and
- bank protection on the waterward slope to prevent erosion of the dike material and undercutting of the toe and face of the dike.

The structural integrity of the dike can be impacted by **seepage** and **piping**. Seepage is the movement of water from the interior of the dike to its exterior. Points of discharge are known as seeps. Excessive seepage can cause localized slope failure. The retention of water due to the lack of adequate drainage of the soils within a dike can also lead to saturated slopes and subsequent large-scale failure. Piping is an erosion process in which water retrogresses through a seepage path, such as a decayed root conduit, forming a hole that increases in size with flow. Piping discharge occurs at the surface through seeps.

Design features that address seepage and piping include:

- impermeable or low permeability cores to prevent through-flow of water; and
- a permeable surficial layer to facilitate drainage, thereby minimizing saturation of substrates.

5.2.1 Design Flood Conditions

To estimate crest elevations and bank protection requirements for riverine dikes, an analysis of design flows should be undertaken. A range of flows, up to and including the design flow event, should be estimated, and water surface profiles corresponding to the design flows should be used to develop suitable crest elevations. For ocean facing dikes, a water level analysis, consisting of an assessment of the effects of storm surge, tides, wave and wind setup is required. A stability analysis of the dike revetment must be carried out, and an evaluation of wave runup and overtopping under storm events should also be considered.

The Inspector of Dikes Office of the provincial Ministry of Sustainable Resource Management sets Flood Construction Levels (FCL) in order to floodproof upland developments to a common standard and to achieve an acceptable level of risk. The FCL is the lowest allowable elevation for the ground floor of an occupied building.

The FCL is equal to either the:

- 200 year maximum daily water level plus 0.6 m of freeboard; or
- 200 year maximum instantaneous water level plus 0.3 m of freeboard.

The highest level for a particular site becomes the FCL.

Design considerations may include an evaluation of proposed and/or existing upland use. Industrial facilities, trailer parks or recreational areas may be able to withstand a greater risk of flooding than would a residential area. For areas accommodating such land uses, the Inspector of Dikes Office may relax the FCL. Other general design considerations are associated with freeboard allowance and seismic requirements.

5.2.2 Diking Standards

Dikes are most frequently constructed or upgraded by a local, provincial or federal authority. As such, structures often follow a pre-set configuration or standard. For example, the standard dike design utilized in the 1968 Fraser River Flood Control Program (FRFCP) employed the following design criteria:

- minimum crest width of 3.6 m, with crest material consisting of 150 mm of crushed gravel;
- horizontal width of the filter and armour layers of erosion protection not included as part of the crest width;
- minimum crest elevation at 1894 flood adjusted level, plus a 0.6 m allowance for freeboard;
- maximum waterside dike slopes of 3.0H:1.0V and 1.5H:1.0V for non-armoured and armoured dikes, respectively;
- typical landside dike slopes of 3.0H:1.0V;
- allowances for toe drains and other drainage features to facilitate free drainage of the dike body;
- for non-armoured dike slopes, 150 mm thick layer of topsoil hydro-seeded with grass seed; and
- for armoured dike slopes, an armour layer thickness of 900 mm, with a filter layer thickness of 300 mm.

The application and width of armoured toe aprons was site specific. Figure 5.1 illustrates a typical FRFCP standard dike in section view.

For lands near the delta front of the estuary, an Accelerated Diking Program was implemented as a result of flood damages sustained during extreme high tides in December, 1982. The following damaged dikes were repaired or reconstructed:

- Mud Bay;
- Colebrook;
- Serpentine and Nicomekl rivers;
- Westham Island; and
- Crescent Beach.

An agricultural design standard was adopted for this program that deviated from the design standard typically implemented by the FRFCP. The outstanding design features of this standard are:

- a reduced crest width of 3.06 m;
- waterside and landside slopes of 2.0H:1.0V;
- a reduced freeboard of 0.3 m; and
- an armoured toe apron 1.0 m in width.

The waterside armouring standard varied from dike to dike. The armouring on the dikes of the tidal portions of the Serpentine and Nicomekl rivers consisted of rounded cobbles (Figure 5.2). The armouring on the Mud Bay and Westham Island dikes consisted of rip rap. Where rip rap was applied, it consisted of a 500 mm thick armour layer with an underlying 300 mm filter layer.

The construction of a dike along a river bank will generally require some bank regrading. Steep or undercut banks may require regrading of the slope to 2.0H:1.0V or less. Depending upon upland uses, bank sloping or grading may be limited by the close proximity of utilities, buildings and/or roadways, costs associated with land acquisition, and/or the requirement to retain existing vegetation. In such situations, a slope of 1.8H:1.0V may be employed to lessen impacts on these resources.

Protection against erosion or scour of dike slopes requires resistant materials. Resistance is typically provided by the mass and interlocking nature of the materials. Structural units made of concrete or gabions may be used; however, within British Columbia, it is most economical to use rip rap.

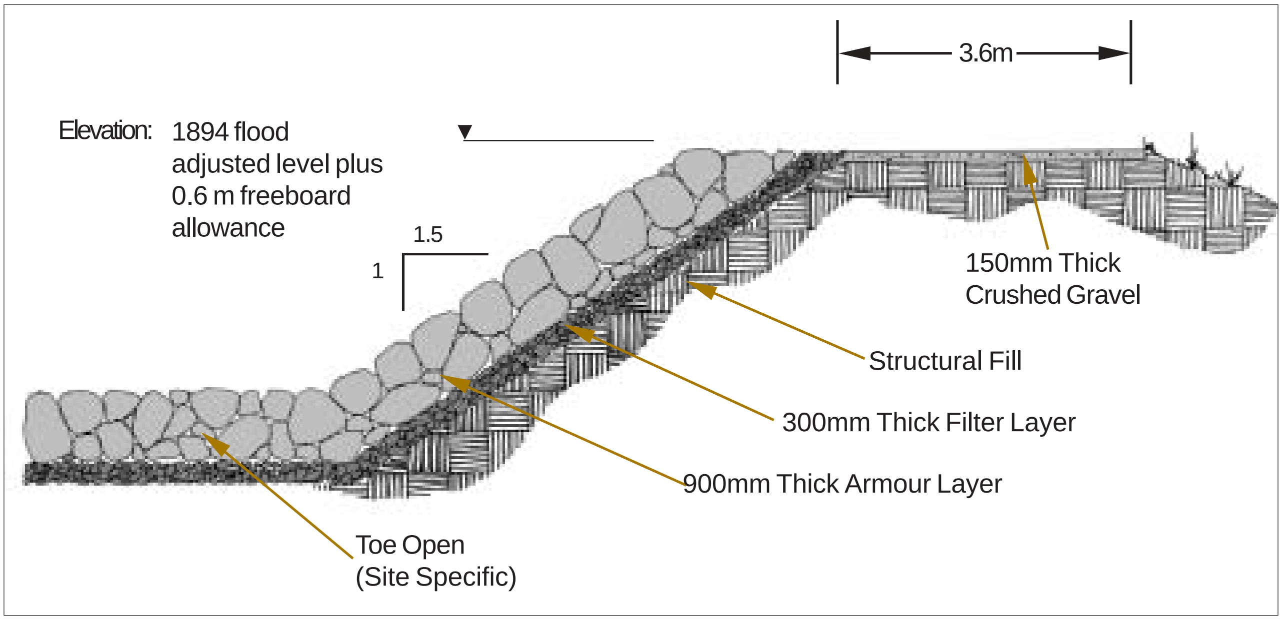


Figure 5.1 Typical Fraser River Flood Control Program dike design.

The reconstruction of dikes and revetments also requires the careful selection and layering of filter rock and other aggregates as bedding materials. These are sorted by size and layered so that smaller sediments cannot be washed out through the interstices of larger rocks. Geotextile can also be used to prevent the loss of finer sediments through larger sized material.

Toe scour can seriously compromise the structural integrity of dikes. To minimize toe scour, toe aprons should be incorporated as part of the dike's overall armament. During construction, the placement of toe aprons involves the excavation of the base of dike and revetment slopes and subsequent infill with rip rap. A toe apron stabilizes the slope and prevents undercutting and slumping.

5.3 Environmental Design

5.3.1 Location

The primary function of dikes is to eliminate the periodic flooding of land. The cause of flooding may be due to daily fluctuations in tides, and/or to seasonal changes in water level. The majority of conventional riverine dikes in British Columbia were built along the natural banks of the main river channel (Figure 5.3). As a result, there has been a significant loss of floodplain woodlands and wetlands, as well as floodplain distributary channels. Similarly, the construction of estuarine and marine dikes has resulted in a significant loss of tidal marshes and swamps, with many tidal channels either lost entirely or converted to drainage canals.

Impacts to natural landscape features can be mitigated through dike location and alignment. **Setback dikes** are the most desirable design option (Figures 5.4, 5.5 and 5.6). Ideally, the dike location and alignment is setback from the main river channel to avoid the majority of the

Figure 5.2 Nicomekl River estuary dike.

floodplain, or is setback beyond the high water mark for frequent flood or tidal events. These setbacks often cannot be achieved due to conflicting land uses, especially within developed areas. Regardless, the objective is to maximize the distance of the setback so as the functional capacity of the affected area as habitat for fish and wildlife is maintained.

From an engineering perspective, setback dikes minimize the impact on flood channels, thereby accommodating conveyance and storage during extreme flood events. Although examples of setback dikes are rare, it is quite likely that construction and maintenance costs of such dikes, relative to the conventional dike design, are decreased due to the position of the dike, lower dike fill volume and lack of exposure to constant erosive forces. Erosion protection for the setback dike is a design option that is dependant upon overbank flow velocities during a flood event. Bank protection may also be implemented in the channel, separate from the dike structure itself.

5.3.2 Vegetation

Vegetation can be incorporated into the overall design of a dike without compromising flood protection. Often, the basic design of the dike does not need to be modified to accommodate vegetation; in other instances, a slight modification in the basic design permits the incorporation of a relatively complex vegetation community.

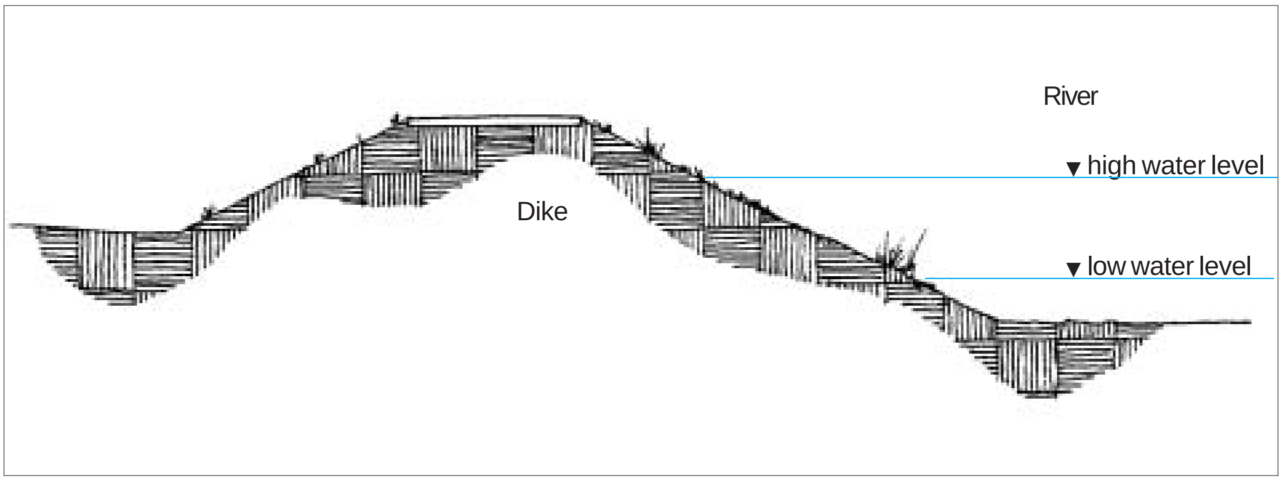


Figure 5.3 Non-setback riverine dike.

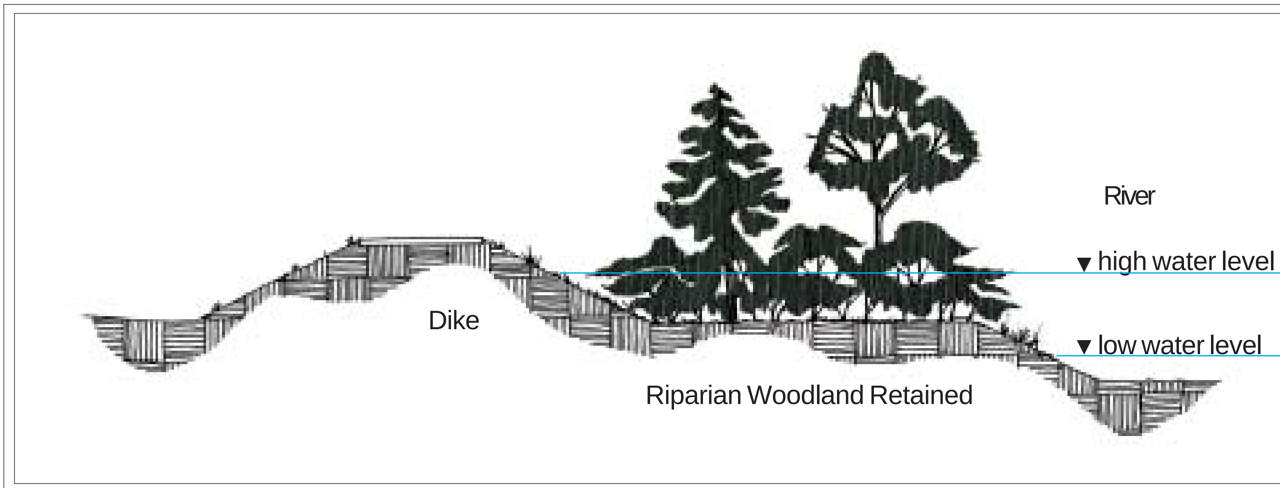


Figure 5.4 Setback dike.

5.3.2.1 Shallow Slope Treatment

For shallow slopes (e.g. dike slopes at 3.0H:1.0V), the incorporation of vegetation, in particular, herbs, grasses and small shrubs, offers long-term protection against surficial erosion and provides some degree of protection (primarily woody species) against shallow mass-movement. Surficial erosion is minimized by vegetation through:

Interception - foliage, organic debris and humus dissipate rainfall energy and prevent the compaction of soil by rain drops;

Restraint - root systems physically bind or restrain soil particles while surficial organic debris and humus filter sediments out of runoff;

Retardation - the surface roughness provided by organic debris and humus slows the velocity of surface runoff;

Infiltration - roots, organic debris and humus contribute to soil porosity and permeability; and

Transpiration - the depletion of soil moisture by plants delays the onset of saturation and subsequent surface runoff.

A list of shrub species appropriate, from an ecological perspective, for use on dike slopes is provided by Table 5.1. These species will also not compromise the structural integrity of dike structures. The list reflects species that express high vigour in an environment that is characterized by: a fluctuating water level regime; little, if any, shade due to the absence of trees; and, non-native soils used to construct the dike that are poor in nutrients and have a limited capacity to retain moisture.

These species perform best when planted as close to the wetted edge as natural conditions will allow, typically in the range of 0.0 to 2.0 m (vertical) above the frequent or normal high water level; more drought tolerant species are appropriate for the uppermost portions of the dike slope where drying of the soils occurs during the summer months. Taxonomic and ecological descriptions for those species presented in the table and other species suitable for riparian and foreshore planting programs are presented in Appendix C.

Figure 5.5 Setback riverine dike, Coquitlam River.

Overbuilt (Figure 5.7) dikes can be shaped to enhance topographic variability, improving both the aesthetic qualities and the functional capacity of the dike as habitat for fish and wildlife. However, overbuilt dikes have limited applications because they have a larger footprint on the landscape,

Figure 5.6 Setback riverine dike, Serpentine River.

Recent upgrade of the dike maintained the setback from the original dike alignment; important shoreline habitats were retained.

Table 5.1 Native Shrub Species for Use on Dike Slopes

Species (Scientific and Common Names)	Form and Size	Rooting Character
Cornus stolonifera red osier dogwood	shrub to 6.0 m in height	shallow, spreading; strong adventitious rooting
Corylus cornuta beaked hazelnut	shrub to 4.0 m in height	extensive, branching
Holodiscus discolor oceanspray	shrub to 4.0 m in height	shallow, spreading
Gaultheria shallon salal	shrub to 3.0 m in height	shallow, spreading
Lonicera involucrata black twinberry	spreading shrub to 3.5 m in height	shallow, spreading
Physocarpus capitatus Pacific ninebark	shrub to 4.0 m in height	shallow, lateral
Rosa spp. wild rose	sparse to dense shrubs to 1.5 m in height	poorly developed
Rubus parviflorus thimbleberry	shrub to 3.0 m in height	shallow, fibrous, extensive
Rubus spectabilis salmonberry	shrub to 4.0 m in height	shallow, fibrous, extensive; reclining stems often set roots
Sambucus racemosa red elderberry	shrub to 7.0 m in height	fibrous, strong adventitious roots
Spiraea douglasii hardhack	dense shrub to 2.5 m in height	fibrous, extensive
Symphoricarpos albus snowberry	dense shrub to 1.5 m in height	extensive, branching, fibrous; spread from rootstocks

potentially impacting productive fish and wildlife habitat and thereby offsetting any environmental benefits associated with their unconventional design.

5.3.2.2 Ecopocket Treatment

The intent of ecopocket planting is to establish vegetation intermittently within the armour layer of the dike. Structures are often incorporated to form the ecopocket within the rip rap treatment while still maintaining the structural integrity of the armament. These structures may consist of steel cylinders, such as corrugated steel pipe, or cylinders constructed of reinforcing steel (i.e. ‘rebar baskets’). Concrete pipe, such as manhole casing, is an alternative pocket structure. Non-woven geofabric may be utilized to line the pockets to retain fill soil. It is important that the structural integrity of the rip rap remain; it is often necessary to have the structures extend through the armour layer.

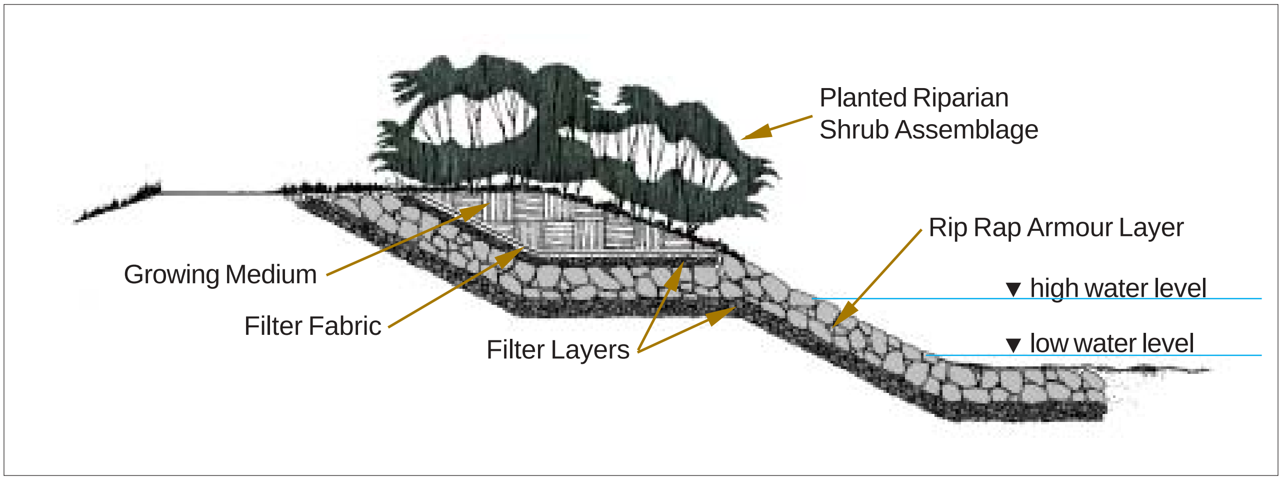


Figure 5.7 Overbuilt dike.

In the absence of structures, pockets may be constructed in an overburden of rip rap on the face of the slope (Figures 5.8 and 5.9). The additional rock forms the pocket. The pocket is lined with non-woven geofabric. Fill soil types and surface elevations are dependant upon design plant species.

5.4.2.3 Bench Treatment

The rip rap revetment of a dike can be modified to incorporate a bench. The bench is a structural extension of the revetment. As described in Chapter 4, the substrate elevation of the bench is dependent on the plant community to be established. The most common application of benches is associated with the establishment of marsh vegetation on the lower slope of the dike. Figure 5.9 displays the application of a relatively wide bench design, while Figure 5.10 presents the typical bench design.

5.4 Maintenance

A prudent and regular schedule of dike inspection and maintenance is typically implemented to identify and upgrade dikes that have deteriorated. Inspections during periods of high flow are carried out to monitor the performance of the dikes and determine if any sections are failing.

Dike maintenance can include:

- dike upgrading;
- vegetation management;
- dike slope repairs;
- bank protection repairs; and
- removal of grounded debris.

5.4.1 Dike Upgrading

5.4.1.1 Freeboard Improvements to Existing Dikes

The freeboard of an existing dike can be increased by adding structural materials to the crest of the dike, inside the outer face of the structure. The freeboard increase provides an additional factor of safety against flooding

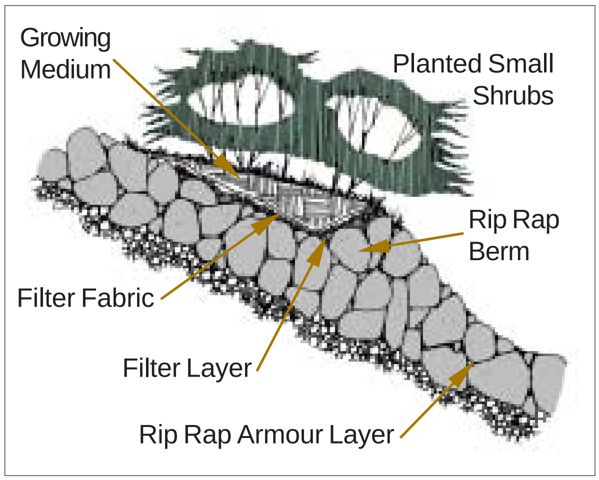


Figure 5.8 Overburden rip rap pocket.

Figure 5.9 Ecopocket (inset: individual ecopocket) and bench treatments, Deas Slough, Main Arm distributary channel, Fraser River.

and overtopping. Working inside the outer face of the dike minimizes impacts to the environment.

5.5.1.2 Setback of Existing Dikes

Habitat enhancements and flood protection improvements can be achieved where riverside dikes currently exist. These dikes can be set back from the channel to provide additional conveyance areas during flood events and provide landscaping opportunities for the restoration and enhancement of riparian habitats.

5.4.2 Vegetation Management

As part of the design of dikes, it is prudent to incorporate vegetation to minimize the erosion of surficial material. Shrubs and trees often become established on dike slopes. Conventional dike management practices dictate the removal of all woody vegetation on dike slopes, regardless of species. The basis of this management approach is that:

- extensive coverage by shrubs and trees on slopes obscures and limits visibility of the slope and toe during dike inspections; this can result in failure to detect evidence of erosion, animal burrows and/or the sloughing

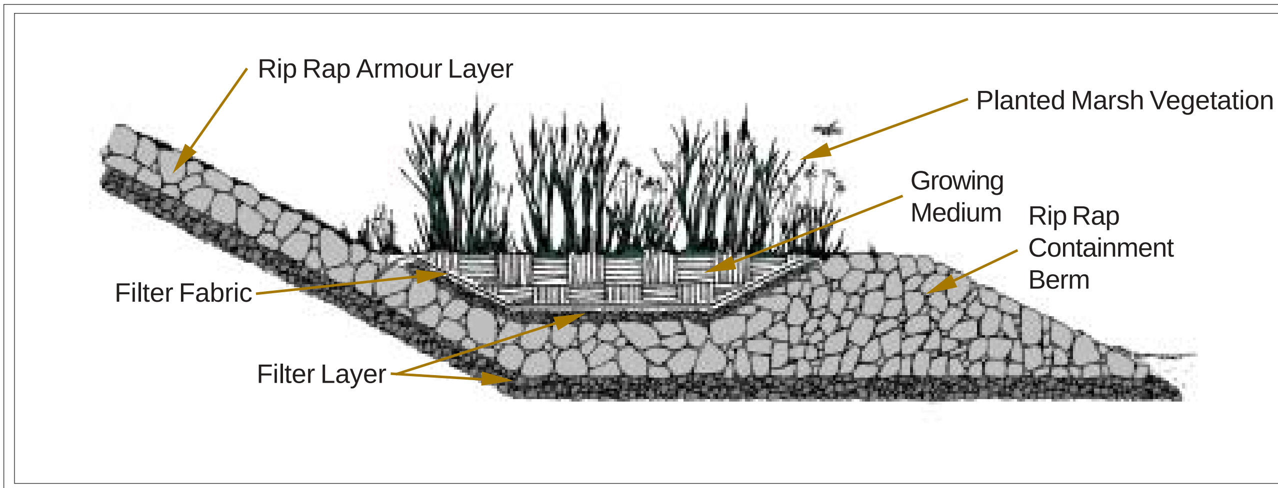


Figure 5.10 Typical bench design.

of rip rap that may contribute to dike failure during a flood event;
- large trees can pose a threat to stability during a flood event, as the dike soils become saturated and the resulting loss of cohesion contributes to uprooting and the falling of trees; this typically results in the displacement of material due to upheaval of the root ball, and can contribute to further erosion and/or structural failure; and
- large trees are susceptible to windfall during storm events; again, the upheaval of the root ball can contribute to erosion and/or structural failure.

Trees are typically removed from dike slopes at an early age prior to the development of an elaborate and massive root system. The root systems often die, and as they are not a significant structural feature of the dike slope, their death and subsequent decomposition does not have a significant impact on the integrity of the slope.

Shrubs hinder the conventional protocol employed for dike inspections as they conceal the lower slope from workers during inspections conducted from the crest of the dike. In those instances where the water body is navigable, inspections can be conducted from the waterward side of the dike, avoiding the need to remove shrub vegetation to facilitate visual inspection.

Unfortunately, dike maintenance programs often do not discriminate between woody vegetation that does and does not obscure and limit visibility (from the landward side of the dike) or threaten the structural integrity of a dike. Shrub communities that sustain significant fish and wildlife habitat values, and pose little threat to the successful maintenance of dike structures, are typically removed. Maintenance programs must include criteria to determine the threat of the prevailing vegetation community to successful dike maintenance. Once the threat is defined, an appropriate maintenance protocol should be developed that mitigates, to the fullest extent practical, impacts to existing fish and wildlife habitat values. A critical component of adequate impact mitigation is the ability of maintenance personnel to identify woody plant species.

Vegetation management of dikes can be improved through the incorporation of some basic ecological principles. Maintaining a dense cover of vegetation, such as grasses and small shrubs, prevents the ready establishment of trees. Maintenance may simply require the physical removal of the relatively few tree saplings that do become established. In those instances where large trees are selectively removed as a measure to protect the dike, the exposed substrates beneath the previous canopy should be seeded or planted with grasses or shrubs, respectively. Integrated vegetation management, where the ecology of plant species is exploited, is a long term maintenance approach that is more economically sustainable than the short term approach characterized by nonselective mowing and cutting.

5.4.3 Slope and Bank Protection Repairs

Traditionally, repairs to the dike slope have generally consisted of regrading the surface and then revegetating the bank, typically with herbs and grasses through hydroseeding. Bank protection works have typically involved the replacement and/or realignment of rock that has been lost and/or moved, respectively, during a flood or storm event.

Where appropriate, the planting of shrubs should be incorporated as part of the repair plan, regardless of whether or not shrubs were part of the previous slope. Environmentally responsible dike maintenance protocols consider the enhancement of natural landscape features for fish and wildlife.

Repair usually commences with the assessment of damage and determination of the cause of damage. Remedial works are designed and submitted to regulatory agencies for review and subsequent approvals. Works involving the regrading of slopes and the handling of rip rap typically require heavy machinery. The potential for impacts to surrounding natural features is high. Accordingly, several precautionary measures should be taken to mitigate the impact of construction activities on the environment.

Schedule repairs to minimize the risk of erosion:

- conduct repairs during dry weather to avoid rain associated degradation of the work site; and
- complete repairs from early spring to early summer to permit rapid establishment of vegetation.

In scheduling repairs, the work program must account for scheduling restrictions for in water works associated with critical life history stages of juvenile and adult salmonids. Local Fisheries and Oceans Canada (DFO) personnel can provide such scheduling restrictions for their areas.

Implement construction practices to minimize disturbance and contain sediments:

- isolate the access areas for heavy machinery;
- provide working pads or surfaces (e.g. quarry tailings) for heavy machinery;
- cover temporary soil fills or stockpiles with polyethylene sheeting or tarps; and
- enclose the downslope perimeter of the work site with silt fencing during extended onsite construction.

Implement a pre-designed comprehensive revegetation plan:

- prescribe a landscape treatment, including specifications for plant species, size and spacings, prior to commencement of construction;
- where feasible, salvage sod and shrubs for replanting once repairs are completed;
- use mulches and other organic stabilizers to minimize erosion until vegetation is established; and
- complete seeding and planting at least one month prior to the end of the growing season.

Comprehensive revegetation plans address both flood protection and habitat conservation design objectives. Collaboration between dike maintenance agencies and DFO, whereby information is exchanged regarding alternative revegetation options, is an important component of the maintenance process.

Establishing Vegetation 6

6.1 Introduction

Native riparian and foreshore vegetation assemblages sustain important life history functions for fish and wildlife. As such, the potential impacts of shoreline development projects on these assemblages are a key consideration during project review. To adequately offset impacts to native vegetation assemblages, the development proponent is typically required by regulatory agencies to conduct landscape works that establish native vegetation. The successful establishment of vegetation is dependent upon sound technical design criteria.

This chapter emphasizes a design philosophy that seeks to create the best environment possible for establishing native vegetation. To ensure the successful establishment of vegetation, the same level of diligence that is afforded the design of conventional structures must be afforded the design of vegetation features. Although this chapter provides design criteria for the establishment of vegetation, it must be understood that the design of vegetation features is a highly site specific endeavour, and that specific design criteria will apply to individual projects.

6.2 Site Preparation

Proper soils are a necessary precursor to project success. Where possible, soils salvaged from sites recently cleared as part of land development activities, which prior to clearing sustained an assemblage of native species similar to that proposed by the vegetation plan, should be utilized. Soils salvaged from these sites should be those that occurred within the upper rooting horizon of the cleared vegetation and should not include subsoils. Soils of the upper horizon contain organic constituents, such as decomposing leaf litter and wood, that complex the soil, afford proper drainage, and slowly release nutrients. They often contain the seed bank of desired vegetation, thereby facilitating the natural establishment of desirable vegetation and the natural succession of species.

Salvaged native soils contain a diverse assemblage of decomposers (Figure 6.1). Of these organisms, mycorrhizal fungi may be of greatest importance to plants. Through interactions with the roots of plants, these fungi assist in the uptake of nutrients and water, resistance to some diseases, and alleviation of stress due to extremes in temperature and moisture. The importance of mycorrhizal fungi for the establishment of new plantings has been recognized to the extent that some landscape contractors offer, as a service, the inoculation of imported topsoils with fungi.

If commercially produced topsoils are to be used, the soils must be free of construction debris (e.g. crushed bricks, glass, metal, etc.) and wood waste (e.g. hog fuel). The soils should be a mix of sand, silt, clay and organics, the proportions of which are dependent on the species to be planted. Table 6.1 presents general criteria for constituents of soils intended for use in terrestrial plantings.

In general, larger shrubs and trees require less organics than herbs, grasses and smaller shrubs. Further, some plants thrive in relatively acidic soil conditions. Soil acidity may be increased through addition of wood residuals and/or peat moss. Wood residuals should be limited to fir or hemlock sawdust. Cedar sawdust should not be used. Peat moss should be of a horticultural grade, with 95 to 100 percent and 0 to 15 percent of the particles passing through a 9.5 mm and 500 *u*m standard sieve, respectively.

When soils require additives to increase nitrogen, phosphorous and/or potassium concentrations, it is recommended that composted manure be utilized rather than chemical fertilizers. Composted manure provides an ideal medium for soil microfauna and fungi, important precursors for the decomposition of organic matter and the subsequent availability of nutrients. The nutrients are slowly released into the

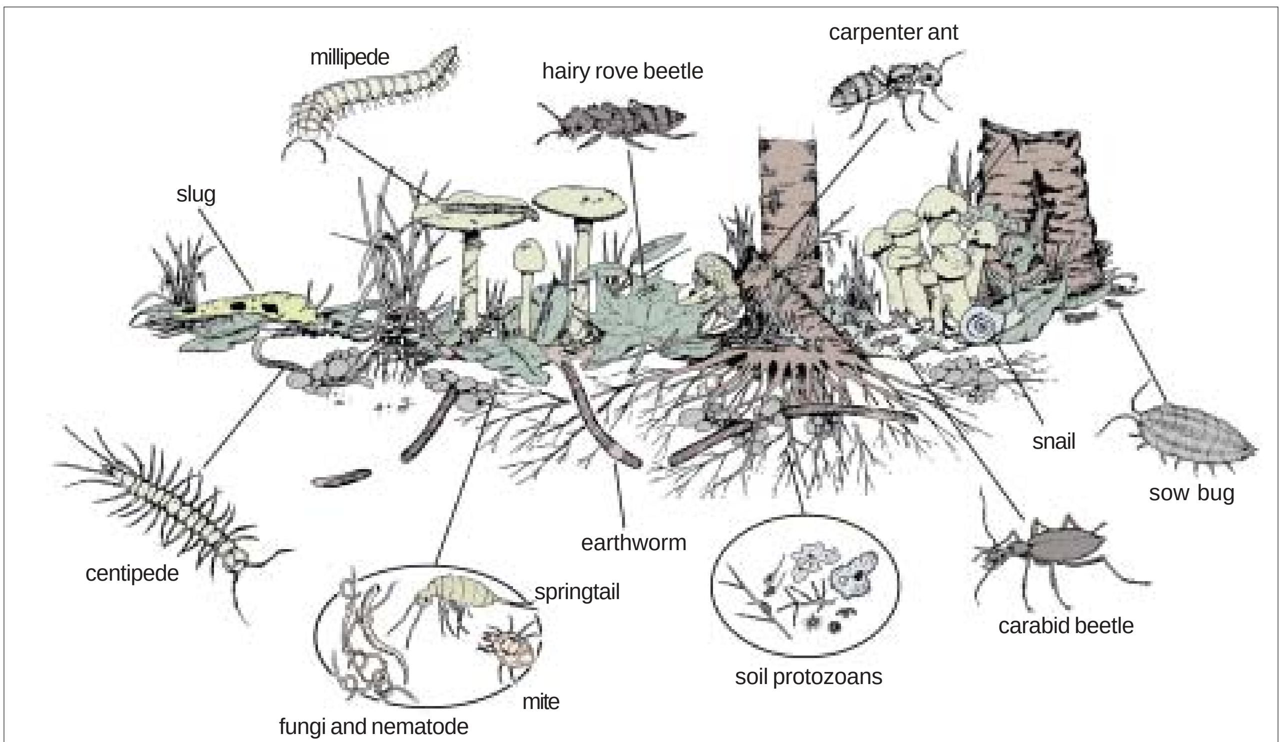


Figure 6.1 Native soils host a diverse assemblage of organisms that greatly facilitate the decomposition of organic matter. Decomposers are consumed by both invertebrate and vertebrate animals. These animals are, in turn, preyed upon by other animals. The use of native soils can greatly enhance the ecology of the project location.

Table 6.1 Riparian Soil Properties

Soil Property		Percent Dry Weight of Mineral Fraction
Texture		
Particle Size Classes		
Gravel	greater than 2 mm less than 75 mm	0-10
Sand[a]	greater than 0.05 mm less than 2 mm	50-70
Silt[b]	greater than 0.002 mm less than 0.05 mm	10-30
Clay[b]	less than 0.002 mm 10-20	
Organic Content		percent dry weight 10-30
Acidity		pH 5.0-6.5
Drainage		percolation should be such that standing water is not visible 120 minutes after a rain event of moderate to heavy intensity of at least 10 minutes.

[a]particle size sand: 95-100 percent pass through a 4.76 mm standard sieve
0-40 percent pass through a 500 um standard sieve
0-5 percent pass through a 53 um standard sieve

[b]silt and clay combined: maximum 40 percent

environment during decomposition of the manure. Specifications for manure include:

- that it be free of harmful chemicals, such as any used to artificially hasten decomposition;
- that the particles in the manure pass a 6.35 mm standard sieve; and,
- that it be relatively free of the viable seed of any plant species, with the maximum of two viable seeds per litre of manure.

Criteria for soils for wetland herbs, rushes, sedges and grasses vary extensively according to species. As a result, a universal standard for wetland soils cannot be achieved. Typically, the soils of desired vegetation, in proximity to the project site, should be sampled and analyzed to develop project specific criteria.

Soil moisture is an extremely important design parameter for both riparian and foreshore planting programs. It is dependent on several factors, including soil type, topography and exposure to sunlight. The intrinsic capability of the soil to retain moisture is primarily dependent upon the particle size of the mineral fraction and the overall content of organic matter. Topography and exposure to sunlight are extrinsic factors that can dramatically influence soil moisture.

Topography includes both the elevation (relative to surface and ground water) and slope or grade. Within riparian environments, the surface water elevation of adjacent rivers often extends well into adjacent riparian soils and into the rooting horizon of riparian vegetation. Although riverine waters may not frequently flood the riparian environment, the prevailing water level regime of the river can certainly impact, both negatively and positively, the vigour of riparian vegetation. Within tidal environments, the period of tidal inundation, which is dependent on elevation, will determine the extent and structure of the foreshore plant assemblage through both soil moisture and the duration of inundation of the aboveground parts of plants. The slope or grade of substrates determines the extent to which water is retained within, or drained from, the soil horizon.

Aspect is the orientation of the site relative to the sun. Aspect changes with changes in slope and direction of exposure. Project sites located on relatively steep north facing slopes may require shade tolerant plants while, in contrast, sites on relatively steep south facing slopes may require plants tolerant of full sunlight and drought conditions during the summer months.

Sites exposed to full sunlight should incorporate a deep soil horizon with relatively gentle slopes or grades. The deep soils provide a mass that behaves somewhat as a reservoir; moisture is retained within the rooting horizon. Drainage is reduced by gentle grades, further enhancing retention of water.

A secondary design feature to reduce moisture loss is the incorporation of a light coloured mulch, such as hemlock or fir wood chips or pasture hay, to reduce heating of the soil by sunlight. Topsoils are relatively dark, readily absorbing solar energy. Evaporation of soil moisture is increased by heating. Light coloured mulches reflect sunlight, reducing the extent to which the soil is heated, and in turn, the rate of evaporation.

While soils should never be permitted to completely dry, soils should also never be permitted to experience prolonged periods of saturation. Prolonged saturation impacts plants within both foreshore and riparian environments; it limits the ability of the roots of plants to respire, often leading to the death of plants through ‘drowning’.

There is a misconception that wetland herbs and grasses require persistent saturated soil conditions, often with water perched above substrate elevations. Persistent saturated soil conditions often result in the drowning of many common wetland plants. For example, tidal marsh creation projects within southwestern British Columbia often seek to establish Lyngby’s sedge (*Carex lyngbyei*) marsh (Figure 6.2). A primary design consideration in the creation of Lyngby’s sedge marshes is the specification of substrate surface elevations consistent with those of native sedge marshes in proximity to the project site. Achieving accurate substrate elevations, however, is only one component of proper site preparation. Adequate drainage is another critical component. Some projects have been able to achieve only partial success in establishing Lyngby’s sedge through neglect of this latter design consideration; substrates drain inadequately, rendering the affected rooting horizon relatively void of oxygen. These areas are markedly apparent by the lack of vegetation.

Soil moisture interacts with the intensity and duration of sunlight to determine the presence and vigour of plants. This is especially pronounced for wetland vegetation. Wetland vegetation is typically very intolerant of shade. Decreases in intensity and duration of sunlight induce decreases in areal cover and biomass. Lyngby’s sedge and slough sedge (*C. obnupta*), two closely allied species, exemplify this relationship between shade and soil moisture (Figure 6.3). Riparian shrubs and trees often overhang and shade tidal marshes. This shading

Figure 6.2 Lyngby’s sedge marsh created immediately downstream of No. 2 Road bridge, Middle Arm distributary channel, Fraser River.

often precludes Lyngby’s sedge from growing at elevations that it would otherwise inhabit. In contrast, slough sedge thrives as groundcover beneath the same shrubs and trees. Careful consideration must be afforded the light regime of the area to be planted with wetland vegetation.

6.3 Species Selection

In general, and in order of decreasing priority, species selected for planting programs should adhere to the following criteria.

Native species characteristic of natural riparian and foreshore plant assemblages

> Projects that incorporate a large area can often sustain the majority of species characteristic of natural assemblages. The ecological interactions of natural systems are complex. Accordingly, rather than specify individual species based on their perceived value as fish and wildlife habitat, natural assemblages of native species should be specified for planting. For riparian woodlands, this includes many groundcover species in addition to shrubs and trees.

Native species that dominate a component of natural riparian and foreshore plant assemblages

Some projects, due to site constraints, do not allow for the establishment of a natural assemblage of native species. In such instances, the specified plant list should at least be comprised of species that dominate natural plant assemblages in proximity to the project site. For example, for riparian projects that traverse power transmission line right-of-ways, there is a restriction as to the height of mature shrubs and trees that can be planted. The ultimate height permitted is dependent upon local topography and the height of transmission lines above the ground. As a result, the plants that can be established are limited to herbs, rushes, sedges, grasses and shrubs that at maturity do not exceed the height restriction. Similarly, a size restriction is often applicable to structures, such as dikes, that may be structurally compromised by large shrubs and trees.

Native species of exceptional vigour

Planting projects are often susceptible to invasion by aggressive, non-native plant species that can quickly establish a monospecific (i.e. single species) cover over portions of the project site. Notable species include blackberry (*Rubus discolor* and *R. lacianatus*) and Japanese knotweed (*Polygonum cuspidatum*) (Figures 6.4 and 6.5). Monospecific stands of non-native plant species within shoreline environments can significantly limit the number of habitat functions these environments can sustain for fish and wildlife.

The provision of food for fish and wildlife by monospecific stands, whether directly provided by the plant (e.g. fruit) or indirectly as an organism that feeds upon portions of the plant (e.g. herbivorous and detrivorous insects), is limited by the temporal availability of such food. For example, the production of fruit by plants is limited to a specific time of the year. As well, insects, particularly life stages, are also available

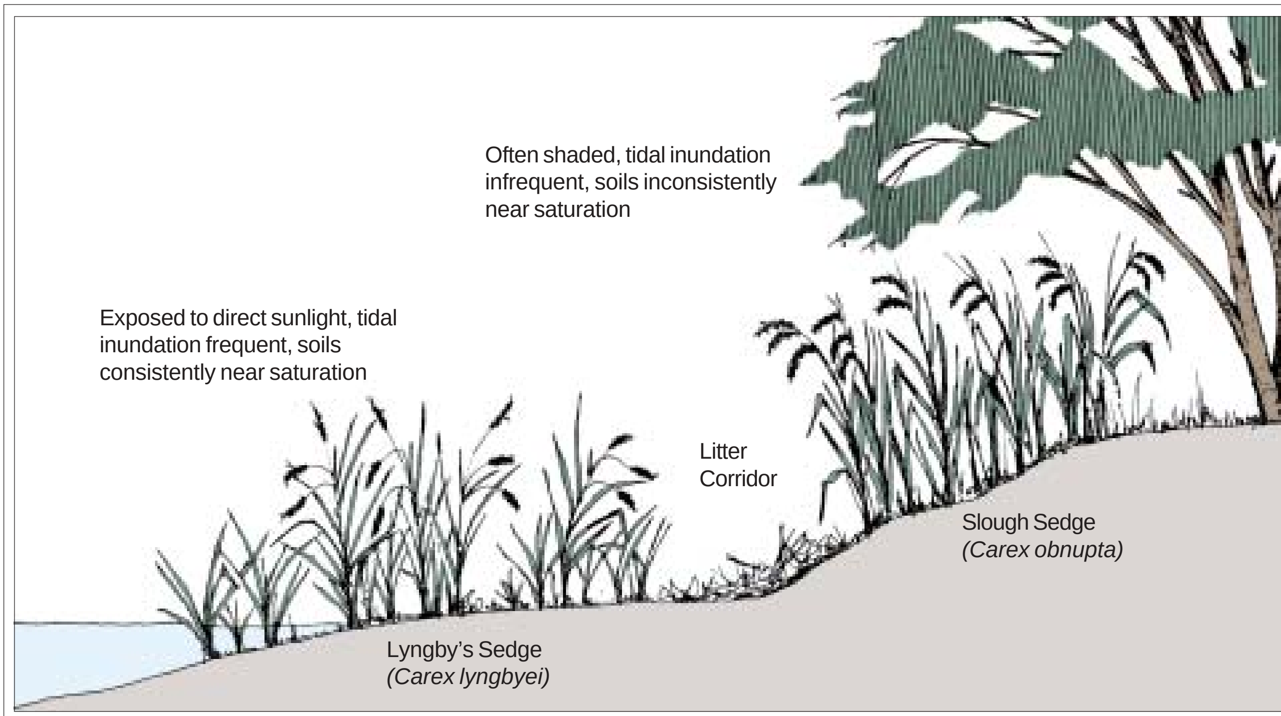


Figure 6.3 Relative sunlight, inundation and soil moisture regimes of Lyngby's sedge and slough sedge.

as prey only during specific times of the year. A diverse assemblage of plant species provides a diverse array of food items, both in terms of type and time of availability.

To minimize the potential for invasion of the planting site by undesirable plant species, it is often necessary to focus the selection of native stock upon plant material that can withstand competitive interactions with such species. For those instances where blackberry is prevalent, the size of the stock at the time of planting often determines whether or not the planted material can survive interactions with blackberry.

Blackberry is notorious for smothering planted material; it readily utilizes many shrubs and small trees as living trestles, quickly blanketing the plants with a matrix of vines and leaves (Figure 6.6). The size of the stock must be as large as possible, with the species selected capable of relatively vigorous growth. Slow growth is a liability; whatever advantage is gained over blackberry by planting large stock would be quickly lost due to the exceptional growth that is often exhibited by blackberry.

If the planting site encompasses, or is close to, thickets of blackberry, the planting plan must prescribe the clearing and grubbing of blackberry. Clearing and grubbing is conducted not only to minimize the vegetative expansion into and within the planting site, but also to minimize the recruitment of blackberry seeds into the project site. The planting of shrubs and trees will facilitate the recruitment of seeds of many species by providing new perching sites for frugivorous birds. During the fruiting period for blackberry, the droppings of these birds will contain the seeds of blackberry. The number of blackberry seeds within these droppings is dependent upon the proximity of blackberries to the perching site.

Figure 6.4 Himalayan blackberry (*Rubus discolor*).

Figure 6.5 Japanese knotweed (*Polygonum cuspidatum*).

Japanese knotweed is an upright, shrub-like, herbaceous perennial that can grow to over 3 metres in height. The stem is jointed, appearing somewhat bamboo-like. Japanese knotweed readily establishes dense thickets within shoreline environments. The plant possesses long stout rhizomes that often form an elaborate and extensive underground network within established stands. As for blackberry, any knotweed within or in proximity to the project site should be cleared and grubbed. The seeds are of little foraging value to wildlife and are readily disseminated by water and wind. The dissemination of vegetative propagules within garden and landscape maintenance waste is also an important means of dispersal; knotweed is particularly prevalent within urban areas.

Where the prospect of colonization or persistence of Japanese knotweed is likely, it is recommended that plants specified by the project design be those highly adapted to the prevailing growing conditions of the project site. Japanese knotweed is extremely tolerant of flooding, drought and salinity. Furthermore, it is recommended that any shrubs specified by project design be those that exhibit a multi-stemmed tufted habit (e.g. ninebark (*Physocarpus capitatus*)); such species are not likely to be extirpated through spatial competition with knotweed. The rhizomes of knotweed simply cannot invade the primary root ball of such plants. Native rhizomatous species, including the relatively aggressive salmonberry (*Rubus spectabilis*), are readily outcompeted for space by Japanese knotweed.

Where the project design includes the clearing and grubbing of non-native plants, such as blackberry and Japanese knotweed, it is imperative that vegetative material and soils containing both vegetative fragments and seeds be disposed of in a manner and at a location that does not result in the propagation of new plants. Furthermore, with regard to the project site, monitoring should be conducted to ensure that seedlings or new shoots emerging from overlooked vegetative fragments are removed.

6.4 Plant Propagules and Planting

The type of plant propagule utilized is dependent on the plant species selected, propagule availability, and the season in which the planting is to occur. Propagules may only be obtained from natural communities during certain times of the year due to the temporal nature of the availability and viability of many

Figure 6.6 Western redcedar 'escaping' Himalayan blackberry.

propagules. This also applies to non-containerized nursery stock, where the spading of material from the field is often restricted to the late fall, winter and early spring when plant material is relatively dormant and the risk of inducing physiological shock in plant material is minimized.

6.4.1 Shrubs and Trees

Propagule types of woody vegetation commonly utilized in fish and wildlife habitat creation projects include cuttings, transplant and nursery stock.

6.4.1.1 Cuttings

Nursery operations commonly use **normal**, **heel** and **mallet** cuttings to propagate plants (Figure 6.7). A normal cutting will root easily for the majority of riparian shrub species and is the type of cutting conventionally used to establish plants in the field. For all types, the cutting must possess several nodes from which new shoots can develop.

The number of species that have been successfully established in the field via cuttings has been limited. Fish and wildlife habitat projects have typically utilized normal cuttings of willow (*Salix* spp.), poplar (*Populus* spp.) and red osier dogwood (*Cornus stolonifera*). Unfortunately, the majority of habitat projects do not incorporate contingencies for the trial of plant establishment techniques that utilize a variety of cutting types and plant species. Referencing cutting technology utilized by nursery operations, there is potential for an increase in the diversity of cutting types and species utilized by habitat projects. Table 6.2 lists common riparian plant species that have been successfully propagated by nurseries utilizing cuttings, with species and cutting types successfully established in the field by habitat projects noted.

Normal cuttings are usually pruned stems or shoots without accessory features. Normal cuttings are the most desirable cutting for fish and wildlife habitat projects due to the relative ease with which they may be inserted into the ground when utilized as live stakes. As with all cuttings, a pair of sharp shears is essential for making clean cuts. Dull shears bruise plant tissues. Damaged tissues are more susceptible to disease and rot, conditions that compromise the viability of the cutting. The ends of the clean cuttings typically callous, thereby preventing rot from reaching viable nodes.

Heel cuttings consist of young side shoots that are stripped away from the main stem so that a thin sliver of bark and wood from the main stem accompanies the shoot. The heel provides an additional barrier to rot.

Mallet cuttings are similar to heel cuttings, but incorporate more of the main stem than a heel cutting. Mallet cuttings should be taken from new stems late in the growing season. A cut is made horizontally across the parent stem immediately above a suitable side shoot. The cut should be made as close to the side shoot as possible to minimize die-back and subsequent rot. A second horizontal cut is made about 2 cm below the top cut so that the side shoot is isolated with a small 'mallet' of the main stem.

The type of wood used for cuttings varies with different plant species and the type of cutting selected. Types are categorized according to the age of the wood and consist of **softwood**, **greenwood**, **semi-ripe** and **hardwood**.

Softwood is the most immature part of the stem and has the highest capacity to develop roots. However, cuttings made of this wood

Figure 6.7 Three basic types of cutting commonly used for propagation.

Table 6.2 Shrub and Tree Species Successfully Established Via Cuttings

Common Name	Scientific Name	Type of Cutting	Type of Wood
willow[a]	*Salix* spp.	normal[a], mallet, heel	softwood, greenwood, semi-ripe, hardwood[a]
black cottonwood[a]	*Populus trichocarpa*	normal[a], mallet, heel	softwood, greenwood, semi-ripe, hardwood[a]
red osier dogwood[a]	*Cornus stolonifera*	normal[a], mallet, heel	softwood, greenwood, semi-ripe, hardwood[a]
black twinberry	*Lonicera involucrata*	normal	semi-ripe, hardwood
red elderberry	*Sambucus racemosa*	normal, mallet, heel	semi-ripe, hardwood
Pacific ninebark	*Physocarpus capitatus*	normal, mallet, heel	semi-ripe, hardwood
Indian plum	*Osmaronia cerasiformis*	normal	semi-ripe, hardwood
salmonberry	*Rubus spectabilis*	normal, mallet, heel	semi-ripe, hardwood
thimbleberry	*Rubus parviflorus*	normal, mallet, heel	semi-ripe, hardwood
snowberry	*Symphoricarpus albus*	normal, mallet, heel	greenwood, semi-ripe, hardwood
hardhack	*Spiraea douglasii*	normal	semi-ripe, hardwood

[a] cuttings utilized by habitat projects

type also exhibit the highest mortality. Softwood cuttings are taken in the spring from the fast-growing tips of plants. They are very susceptible to water loss through newly emerged leaves. Even a small amount of water loss will hinder root development. If leaves on a new cutting wilt, all root development typically ceases and the cutting dies.

Greenwood cuttings are taken from the soft tip of the stem after the spring flush of growth has slowed. The cut stem is slightly harder and 'woodier' than a softwood cutting. Greenwood cuttings have a limited ability to develop roots. Cuttings should be taken early in the morning from a fully turgid stem. The cutting should be immediately placed in a bucket of water or polyethylene bag in a shaded location to prevent water loss.

Semi-ripe cuttings are those taken at the end of the growing season in late summer. They are thicker and harder than softwood cuttings and are therefore more robust. They are still susceptible to the problems of water loss as they still possess leaves. Semi-ripe cuttings can be taken from a main stem or from the side shoots. The tip of the stem should be removed if it is soft and fleshy; retain the tip if the apical bud has hardened and growth has ceased for the year.

Hardwood cuttings are the easiest and most common cutting utilized in habitat projects.

A hardwood cutting is made during the dormant season from the fully mature stem of a deciduous shrub or tree. As there are no leaves present, the potential for water loss is minimized. Hardwood cuttings may be taken at any time during the dormant season.

Normal and heel cuttings may be taken from softwood, greenwood, semi-ripe and hardwood stems. Mallet cuttings are restricted to semi-ripe and hardwood stems.

The application of rooting hormones to cuttings can enhance root development. The most common and best suited rooting hormone is beta-indolyl-butyric acid (IBA). Softwoods and greenwoods are treated with 0.2% IBA. Semi-ripe and hardwoods are treated with 0.4% IBA.

Cuttings may be individually **live-staked** or incorporated as **wattles**. Cuttings must not be allowed to dry. It is preferable that they be used shortly after harvest from parent stock. If there is a delay between harvest and planting that could result in drying, cuttings should be stored in refrigeration compartments in the dark (to prevent shoot elongation) and in a moist condition.

Live-stakes should incorporate at least 4 nodes and be cut so that a node is within 2.5 cm of the top of the cutting (Figure 6.8). Cuttings from 2.0 to 4.0 cm in diameter and 30 to 45 cm in length are typically preferred for staking.

Live-stakes are planted with the bottom of the cutting in the ground. At least two nodes should be entirely buried in the ground. Avoid damaging or stripping the bark or bruising the stakes when planting. Within soft soils, the stakes may be driven in by hand or with a wooden maul. An axe or heavy hammer should not be used; considerable damage to the cutting will result. It may be necessary to set holes in the ground for the stakes (within well consolidated soils). In all instances, the soils should be firmly compressed against the stakes to minimize water loss. No more than 10 cm of the cutting should be exposed after planting.

Wattles consist of stems tied together as a bundle (Figure 6.9). The minimum size of the cuttings is often dependent on the species selected, but in general, the diameter of the cuttings should not be below 1.25 cm. The number of cuttings varies with the size and species of plant material. The cuttings are placed within the bundle with the largest diameter ends alternating. When compressed and tightly tied, the bundles should be 10 to 15 cm in diameter and taper at each end (i.e. cigar shaped). Tying is accomplished by holding and compressing the bundle with two or more loops of binder's twine or similar material. Ties are placed 30-40 cm apart using non-slipping knots.

The wattles are placed within excavated trenches. The trench should be shallow, the depth approximately 3/4 of the diameter of the wattle (Figure 6.9). The wattles are held in place on the downhill side of the trenches by anchor stakes that are driven through the bundles at a maximum spacing of 50 cm. A minimum of two stakes should be used for each bundle. A stake should always be placed at each bundle tie. The trenches are re-filled with soil. All voids within and surrounding the wattle must be filled. The soils must be firmly packed to prevent drying of the cuttings.

Anchor stakes may consist of several material types. Live-stakes are desirable as they ultimately add plant cover. They are, however, easily damaged and are generally best applied within unconsolidated soils. In most instances, stakes composed of dimension lumber are the most effective type.

Wattles have been increasingly utilized to top-dress the rock-armoured surfaces of river banks. The wattles may be tied directly to rocks of the armour layer, or tied to a plastic or wire mesh that lies beneath the armour layer. The wattles are configured as a grid, with both horizontal and vertical components. The interstices of the rocks are filled with soil. Nursery grown sod is placed within each of the grid squares. The wattles are partially buried in soil. Back channels, such as that constructed at Sapperton

Landing, Fraser River, are ideal candidates for this treatment (Figure 6.10).

6.4.1.2 Nursery and Transplant Stock

Wherever possible, nursery stock should be utilized to establish natural assemblages of native species (see Figure 6.11 for types of nursery stock). Furthermore, it is preferable that nursery stock be propagated from seed and cuttings, with the collection of native plants and subsequent incorporation into containers discouraged. Sources of native plant material may be obtained from the British Columbia Landscape & Nursery Association. The Association provides an annotated list of native plants commercially grown in British Columbia at www.canadanursery.com/bclna/native.shtml.

Transplants of native vegetation should be considered only when nursery stock is not available. Prospective donor sites should be assessed as to their capability to withstand the removal of plants. Plant removal must not significantly alter the species membership or structure (e.g. age, size, habit, etc.) of the assemblage.

Ideal donor sites, especially for shrub and tree species, are those sites for which there is pending land development. Comprehensive planning, whereby plant material on pending development sites is inventoried, facilitates the procurement of donor material without undue impacts on natural communities. Collected material may be stored and grown within a nursery, where propagation utilizing a variety of techniques could increase both the number and size of the original material.

Bare root transplants (where shrubs and small trees are excavated, transported without native soil surrounding the root mass) should be performed only during late winter, prior to the swelling of buds. Bare root stock should be planted immediately after extraction. The roots must be kept moist to minimize root death. Bare root transplants are best conducted during wet weather.

Figure 6.8 Live-stake with newly emerged shoots.

Figure 6.9 Willow wattles being installed along the bank of Derby Reach, Fraser River.

Balling and burlapping involves excavating a large proportion of the root mass and associated soil and wrapping it in burlap cloth. It is best performed during late winter; it should not be performed when the plants are in flower and/or during mid to late summer.

The balls (roots and soil) should be solid and wrapped tightly with 142 gram jute burlap. Balls up to 50 cm in diameter may be wrapped without the support of heavy twine or rope. Double burlap may be used on balls of 50-60 cm in diameter in lieu of twine. Balls 60 cm and larger in diameter should be drum laced at 20 cm spacing using 6 mm rope. In general, the root ball diameter should be at least ten times the calliper of the shrub or tree, 50 percent of the height of plants less than 1 m in height, or 30 percent of the height of plants 1 to 3 m in height.

It is critical that the ball is large enough to incorporate a high proportion of young roots. Too often, the old, woody portion of the root mass is all that is incorporated in the ball. This results in the delayed expansion of the root mass into the new soil and/or the ultimate death of the plant.

Container stock is the ideal propagule type for shrubs and trees. The damage to roots associated with either bare root transplants or balling and burlapping is avoided. Unfortunately, container sizes are typically limited to standard no.1, no.2 and no.3 sizes. Although large containers are available (e.g. no.15 size), large plants are often field grown for later balling and burlapping.

6.4.2 Forbs, Rushes, Sedges and Grasses

To date, forbs, rushes, sedges and grasses have predominantly been limited to planting projects for wetland assemblages, such as marsh, wet meadow and swamp. They have been typically omitted from projects within non-wetland riparian environments. Successful integration of all components of a natural plant assemblage, including non-woody species, is key to achieving habitat functions important to fish and wildlife.

Figure 6.10 Wattle grid treatment within a constructed tidal back channel at Sapperton Landing, Fraser River: wattle grid installed on surface of rock revetment (top); and, infilling of grid squares with soil and sod (bottom).

Commonly used propagule types for non-woody plants are **sprigs**, **rhizomes**, **tubers**, **plugs** and **sods**, **cuttings** and **seeds.** Currently, there is limited stock available from commercial nurseries, with transplant stock being the primary source of material for projects with a limited time frame. Nurseries are, however, capable of growing material for projects (Figure 6.12) given sufficient notice (at least one growing season). Stock grown by commercial nurseries is typically available as plugs of various sizes, 4 inch pots and no.1 pots (Figure 6.13).

bare root ball and burlap container

Figure 6.11 Nursery and transplant stock types for shrubs and trees.

For those propagules that require extraction of plant material from native donor sites, care must be taken to minimize the impact on the donor plant community. As the propagules are generally small in size, donor stock extraction should be conducted manually, thereby avoiding impacts to the donor site typically associated with heavy machinery. Material should be extracted at intervals that will allow for quick re-establishment of cover by impacted vegetation. The treatment of holes resulting from excavation is dependent on the environment from which the material is being extracted. Within wetland environments, for high sedimentation regimes and/or loosely consolidated soils, the holes may be simply collapsed using a large dibble; for low sedimentation regimes and/or firmly consolidated soils, the holes should be filled with substrates suitable for the growth of impacted vegetation. Holes created within upland environments should be filled with soil typical of those soils in which the impacted vegetation is rooted.

6.4.2.1 Sprigs

A **sprig** is composed of a single stem and associated roots, or a basal shoot and short rhizome sections (Figure 6.14). Depending on the species, it may be necessary to trim the stem so that the plant stands upright when planted. As the roots of many rhizomatous species are annual, old roots may be stripped from the stem and/or rhizome. Care should be taken when handling new roots. New roots are white or light in coloration. Old roots are dark and often exhibit tissue death and rot. Rhizomatous species of *Carex*, *Scirpus* and *Juncus* are the best candidates for sprigs.

6.4.2.2 Tubers and Rhizomes

Tubers and **rhizomes** are underground perennial structures (Figure 6.14). Although roots often emerge from tubers and rhizomes, tubers and rhizomes are distinct from roots in structure and function. Both tubers and rhizomes are modified stem structures. They are primarily storage organs and often appear swollen. In contrast, roots are structures separate from stems. They absorb water and nutrients from surrounding soils and convey them to other parts of the plant. Roots are primarily anchorage structure for above-ground parts.

Transplants of tubers and rhizomes should be performed during late winter and early spring when the plants are dormant or in the early stages of growth. Viable propagules are lightly coloured. Healthy tubers are hard while healthy rhizomes are somewhat elastic. Rhizomes may be cut into sections that have identifiable nodes (often identified by a concentration of roots at a single location). Species of *Carex*, *Scirpus* and *Typha* are excellent candidates for rhizome cuttings; the rhizomes are large, robust and easily identifiable. *Eleocharis* and some species of *Juncus* possess small, relatively fragile rhizomes that are often damaged during extraction and planting; these species should be transplanted using sediment-root-rhizome plugs. The morphology of tubers is dependent on the species. For example, viable skunk cabbage (*Lysichiton americanum*) tubers should include the apical bud and tuber. Viable *Typha* tubers should possess at least two nodes to ensure shoot elongation in the spring.

6.4.2.3 Plugs and Sods

Plugs and **sods** are composed of stems, roots, tubers and/or rhizomes, and associated substrates. A common device for extracting plugs of marsh vegetation is a golf green cup cutter that extracts a cylindrical plug 10 cm in diameter and 20 cm in length (Figure 6.15). Plugs may also be extracted using a large dibble. Sod size is variable depending on the method of extraction and mode of transport. Sod may be extracted using spades or other sod cutting devices.

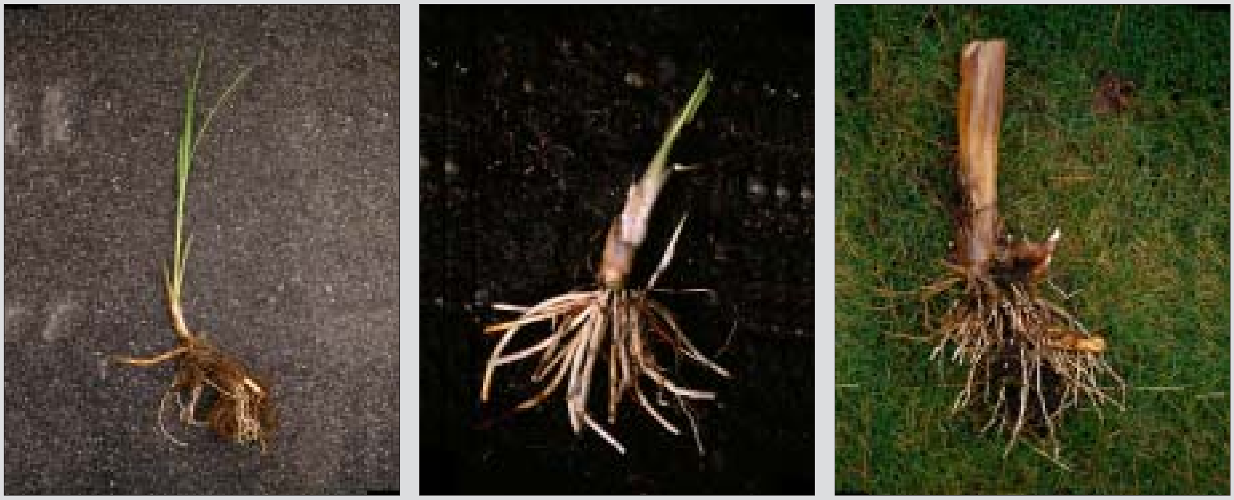
The majority of forbs, rushes, sedges and grasses can be transplanted as plugs and sods. For tufted species, such as soft rush (*Juncus effusus*), woolly bulrush (*Scirpus cyperinus*) and arrowgrass (*Triglochin maritimum*), the size of the plug or sod consists of the entire plant. Plant species characterized by large, robust rhizomes and tubers, such as skunk cabbage and *Typha*, are inappropriate for transplant as the plug or sod often incorporates only a part of the viable belowground structure; damage to such structures often results in plant death.

6.4.2.4 Cuttings

Cuttings are clipped, above-ground vegetative material that are taken off species that naturally root from stem nodes. Cuttings are often raked into the substrate of the project site. Good candidates for cuttings are pickleweed (*Salicornia virginica*) and bentgrass (*Agrostis* spp.).

Figure 6.12 Native plant nurseries are well prepared to grow native forbs, rushes, sedges and grasses for projects.

Figure 6.13 Planting no.1 pot Lyngby's sedge at Burnaby Big Bend, North Arm distributary channel, Fraser River (inset: sedge with pot removed).



small-fruited bulrush sprig skunk cabbage tuber cattail tuber and rhizome

Figure 6.14 Examples of common propagule types for marsh plants.

6.4.2.5 Seeds

To date, the primary focus of **seeding** has been to stabilize disturbed and exposed soils of a project site. Often, non-native clovers (*Trifolium* spp.) and a mix of native and non-native grasses comprise the majority of the seed mix applied to a site. Although seeds of native plant species are readily available from commercial suppliers, seeding to establish a desired assemblage of non-woody species has rarely been conducted.

Where soil stabilization is a priority, seeds of desired species may be used to augment the stabilization mix. The species selected should possess seeds that germinate readily. The species should be those that can maintain a foothold amongst the stabilization species. The focus should be on tufted and aggressive stoloniferous and rhizomatous species. Biennial and perennial species should be prioritized.

In seeding wetland environments, care must be taken to seed during drawdowns that expose wetland substrates for a period sufficient to achieve germination and substantial root and shoot elongation. The substrates must remain saturated. The seeds should be gently raked into the soil. Flooding prior to germination will result in a significant loss of seed due to flotation. The flooding and complete submergence of young shoots will result in considerable mortality due to drowning. Vegetation establishment within wetland environments utilizing seeds requires the ability to manipulate water levels and monitor seed germination and plant growth during the initial establishment period.

For those environments above normal high water, the success of seeding is greatly improved when mulch is used. If the mulch is applied prior to seeding, the seeds should be

Figure 6.15 Extracting Lyngby's sedge plug from donor marsh using golf green cup cutters (inset: cup cutter plugs of sedge).

gently raked into the mulch. Seeding is best applied in conjunction with the application of mulch. The mulch adheres to the soil, holding the seed in place until germination.

6.5 Maintenance

Maintenance is a key component of any planting program. For most projects, maintenance typically consists of the irrigation of material planted within upland environments and the removal of undesirable non-native species within all environments. During the initial growing season, irrigation may be required every two to three days. Undesirable plant species should be removed early in the growing season when individuals are small and easy to remove. The duration of the maintenance program is project specific and should include the initial growing season. Extended plant maintenance, lasting for several growing seasons, facilitates the successful establishment of a natural assemblage of native plant species.

Appendix A: Glossary

The following terms are defined in the context of their use by the main body of this publication.

acclimatize	to habituate to new environmental conditions, such as juvenile salmon when they habituate to brackish and salt water upon entering the lower reaches of an estuary
ambient	that which is freely surrounding, such as water that is not bound within soil or organisms
aspect	the direction of exposure
bathymetry	physical relief features or the surface configuration of the ocean bottom or some other large body of water
biennial	a plant that lives for two growing seasons or years, germinating, growing and storing food reserves in below ground structures during the first year, and flowering and setting seed during the second year; biennials are herbaceous
biophysical	that which is living and non-living, as it relates to the traits or characteristics of a specific environment
bog	an acidic wetland characterized by *Sphagnum* peat
brackish	with reference to water characterized by salinities substantially below that of sea water, ranging from greater than 0.5 to approximately 17 parts per thousand; also with reference to environments, and the organisms and communities inhabiting these environments, characterized by such water
bulkhead	an engineered structure, such as a sheet pile wall, that retains fill within a shoreline environment
compensation	measures taken, such as the creation of new habitat or the enhancement of existing habitat, to offset residual impacts (i.e. where mitigation does not offset all negative impacts) to habitat caused by shoreline development
conveyance	the act of conveying or transporting water flows
coppice	to grow new stems from a recently cut stump
detritus	particulate material composed of organic matter (i.e. dead plant and animal matter) and decomposer organisms such as fungi and bacteria
diffusion	the spreading, scattering or distribution of light
distributary	with reference to a channel that conveys part of the flows of another, such as those channels that convey the flows of the main channel of a river through a delta

ectone	transition zone between two structurally different communities
estuary	a semi-enclosed body of water, which has an open connection to the ocean, where at its seaward margin sea water is measurably diluted by fresh water derived from land drainage, and at its landward margin water levels are measurably altered by tides
fen	an acidic wetland characterized by sedge peat; a typical feature is a low gradient stream or pond that slowly conveys surface flows through the wetland
fetch	a wave generated by wind
floodplain	level lowland along the margins of the hydraulic channel(s) of a stream or river onto which water flows during flood stage
foreshore	the area along the shoreline between low water and high water elevations; low water and high water elevations are a function of tides and/or seasonal water levels within a stream or river
fresh	with reference to water characterized by salinities no greater than 0.5 parts per thousand; also with reference to environments, and organisms and communities inhabiting these environments, characterized by such water
intertidal	pertaining to that area along the shoreline between low tide and high tide water elevations
inundation	flooding or submergence; the act of causing an object to be beneath the surface of water
marsh	a wetland that is typically characterized by shallow water and by emergent aquatic plants such as cattail, sedges, rushes and grasses
media	soil; organic and inorganic material suitable for the planting of vegetation
mitigation	measures taken to minimize impacts to habitat caused by shoreline development, such as the replacement of fill with piles to reduce the footprint of a structure
monospecific	of a single species, such as a tidal marsh comprised entirely of Lyngby's sedge (*Carex lyngbyei*)
mycorrhizal fungi	fungi in association with the roots of vascular plants; such fungi break down compounds to basic components, such as nitrogen and phosphorous, that can be readily absorbed by vascular plants; in turn, carbohydrates, synthesized by vascular plants, are absorbed by the fungi
nearshore	in close to proximity to the shoreline, either from water or land
pan	natural shallow depression containing water or mud; within salt and brackish environments, the evaporation of water creates hypersaline conditions
percolation	the process by which water flows through the interstices of substrates

perennial	a plant that lives for more than two growing seasons or years
permeable	porous; capable of passing water
pier	an engineered structure that projects out into a body of water, typically at 90° to the shoreline
propagules	part of a plant, such as a cutting or seed, that can give rise to a new individual plant
revetment	engineered protection of a slope
riparian	within and in close proximity to the hydraulic channel of a stream or river
rip rap	angular rock
salt	with reference to water characterized by salinities approaching those of sea water, from greater than 17 to 30 parts per thousand; also with reference to environments, and the organisms and communities that inhabit these environments, characterized by such water
salt wedge	a layer of salt water that lies beneath a layer of fresh water within the lower reaches of an estuary; the separation of the two layers persists as the fresh water is substantially less dense than the salt water and the water column is not sufficiently mixed by wave and tidal action; the salt water layer decreases in depth with increasing distance from the ocean due to the increasing elevation of the channel bottom, with the upstream point defined by an intercept with the bottom; the salt wedge moves downstream and upstream within the distributary channels of an estuary with outgoing and incoming tides, respectively
saturation	at which point a soil or other medium can not receive or store more water
seismic	with reference to earthquakes
strata	structural layers, such as those defined by distinct substrates of sediments or those defined by canopy, subcanopy and groundcover of a woodland
subtidal	pertaining to that area of the shoreline below the low tide elevation
swamp	a wetland that is typically characterized by saturated soils and by shrubs and trees tolerant of saturated soils and periodic inundation
transplant	the extraction plant material, its transport, and subsequent planting from one location to another
wake	a wave generated by watercraft

Appendix B: Bibliography and Photographic Credits

Chapter 1

B1.1 Photographic Credits

Chapter Cover		Mark A. Adams
Page 2	Figure 1.1	Province of British Columbia

Chapter 2

B.2.1 Bibliography

Adams, M.A., and G.L. Williams. in press. **Chapter 14: Tidal Marshes of the Fraser River Estuary: Composition, Structure and a History of Marsh Creation Efforts to 1997** *in* Fraser River Delta: Issues of an Urbanized Estuary. Geological Survey of Canada, Vancouver, BC.

Hart, J.L. 1973. **Pacific Fishes of Canada**. Fisheries Research Board of Canada. Bulletin 180. 740p.

Hourston, A.S., H. Rosenthal and H. von Westernhagen. 1984. **Viable hatch from eggs of Pacific herring (*Clupea harengus pallasi*) deposited at different intensities on a variety of substrates.** Canadian Technical Report of Fisheries and Aquatic Sciences No.1274. 19p.

Phillips, R.C. 1984. **The ecology of eelgrass meadows in the Pacific Northwest: A community profile**. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85p.

Seliskar, D.M., and J.L. Gallagher. 1983. **The ecology of tidal marshes of the Pacific Northwest coast: a community profile**. U.S. Fish and Wildlife Service. FWS/OBS-82/32. 65p.

Williams, G.L. 1989. **Coastal/Estuarine Fish Habitat Description and Assessment Manual. Part 1 - Species/ Habitat Outlines.** *Prepared by* G.L. Williams and Associates Ltd., Coquitlam, BC. *Prepared for* Supply and Services Canada, Hull, QU. 129p.

Ricketts, E.F., J. Calvin, J.W. Hedgpeth and D.W. Phillips. 1985. **Between Pacific Tides.** 5th Edition. Stanford University Press. Stanford, CA. 652p.

Kozloff, E.M. **Seashore Life of the Northern Pacific Coast**. 1973. University of Washington Press. Seattle, WA. 370p.

B.2.2 Photographic Credits

Chapter Cover			Mark A. Adams
Page 6	Figure 2.1		Mark A. Adams
Page 9	Figure 2.3		Mark A. Adams
	Figure 2.4		Mark A. Adams
Page 10	Figure 2.5		Otto E. Langer
Page 11	Figure 2.7		Rick Harbo
Page 14	Figure 2.9		Mark A. Adams
	Figure 2.10		Mark A. Adams
Page 15	Habitat Partitioning:		
	Yellow Headed Blackbird		
		Habitat	Canadian Wildlife Service
		Bird	R. Wayne Campbell
		Nest	John M. Cooper
	Red-winged Blackbird		
		Habitat	Mark A. Adams
		Bird	R. Wayne Campbell
		Nest	R. Wayne Campbell
	Brewer's Blackbird		
		Habitat	Mark A. Adams
		Bird	R. Wayne Campbell
		Nest	R. Wayne Campbell
Page 16	Figure 2.11		Eric D. Beaubien
	Figure 2.12		Scott Barrett

Chapter 3

B.3.1 Bibliography

Adams, M.A. and K.E. Asp. 2000. **Habitat and Development Classification System – User's Manual and Map Sheets 'Courtney River Estuary Management Plan'.** *Prepared by* ECL Envirowest Consultants Limited, New Westminster, BC. *Prepared for* Fisheries and Oceans Canada, Nanaimo, BC. 9p + maps. www-heb.pac.dfo-mpo.gc.ca/english/cremp/.

Fisheries and Oceans Canada. 1986. **Policy for the Management of Fish Habitat.** Fisheries and Oceans Canada, Ottawa, ON. 30 p. www-heb.pac.dfo-mpo.gc.ca/english/publications.htm.

Fisheries and Oceans Canada. 1995. **Directive on the Issuance of Subsection 35(2) Authorizations**. Fisheries and Oceans Canada, Ottawa, ON. 6p. www.dfo-mpo.gc.ca/habitat/publications_e.htm.

B.3.1 Bibliography contd

Fisheries and Oceans Canada. 1998. **Habitat Conservation and Protection Guidelines.** Second Edition. Fisheries and Oceans Canada, Ottawa, ON. 20p. www-heb.pac.dfo-mpo.gc.ca/english/publications.htm.

Fisheries and Oceans Canada. 1998. **Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat**. Fisheries and Oceans Canada, Ottawa, ON. 22p. www.dfo-mpo.gc.ca/habitat/publications_e.htm.

Water and Land Use Committee. 1994. **An Estuary Management Plan for the Fraser River.** Fraser River Estuary Management Program, New Westminster, BC. 113p.

www3.ec.gc.ca/EnviroRegs

www.archaeology.gov.bc.ca

www.bc-land-assets.com/water/

www.bieapfremp.org

www.ceaa-acee.gc.ca

www.dfo-mpo.gc.ca/habitat/

www.eao.gov.bc.ca

www.gov.bc.ca/wlap/

www.pacific.ccg-gcc.gc.ca/nwp/

www.pyr.ec.gc.ca

apps.icompasscanada.com/lrc/

B.3.2 Photographic Credits

Chapter Cover	Mark A. Adams

Chapter 4

B.4.1 Bibliography

Hutton, K.E. and S.C. Samis. 2000. **Guidelines to protect fish and fish habitat from treated wood used in aquatic environments in the Pacific Region**. Canadian Technical Report of Fisheries and Aquatic Sciences 2314. 34p. www-heb.pac.dfo-mpo.gc.ca/english/publications.htm.

Witherspoon, B., and R. Rawlings. 1994. **Shoreline Access Design Guidelines for Washington Marine Shoreline Habitats**. Unpublished Manuscript. Washington State Department of Natural Resources, Olympia, WA. 58p.

Anonymous. 1995. **Marina Development Guidelines for the Protection of Fish and Fish Habitat**. Unpublished Manuscript. Fisheries and Oceans Canada, Vancouver, BC and BC Ministry of Environment, Lands and Parks, Victoria, BC. 66p. www-heb.pac.dfo-mpo.gc.ca/english/publications.htm.

Sharpe and Diamond Landscape Architecture. 1997. **Access Near Aquatic Areas: A Guide to Sensitive Planning, Design and Management.** Fisheries and Oceans Canada, Vancouver, BC and BC Ministry of Environment, Lands and Parks, Surrey, BC. 82p. www-heb.pac.dfo-mpo.gc.ca/english/publications.htm.

Western Wood Preservers Institute and Canadian Institute of Treated Wood. 1997. **Best Management Practices for the Use of Treated Wood in Aquatic Environments.** Unpublished Manuscript. Western Wood Preservers Institute, Vancouver, WA. 35p. www.wwpinstitute.org.

Sinnott, T.J. 2000. **Assessment of the Risks to Aquatic Life from the Use of Pressure Treated Wood in Water.** Unpublished Manuscript. Division of Fish, Wildlife and Marine Resources, New York State Department of Environmental Conservation. 45p. www.dec.state.ny.us/website/dfwmr/habitat/hoa1b3.htm.

B.4.2 Photographic Credits

Chapter Cover		Mark A. Adams
Page 30	Figure 4.1	Mark A. Adams
	Figure 4.2	Mark A. Adams
	Figure 4.3	Mark A. Adams
Page 31	Figure 4.4	Mark A. Adams
	inset	Otto E. Langer
	Figure 4.5	Fraser River Port Authority
	Figure 4.6	Otto E. Langer
	Figure 4.7	Gary L. Williams
Page 35	Figure 4.12	Mark A. Adams
Page 37	Figure 4.15	Robert Cochrane
Page 39	Figure 4.17	Mark A. Adams

Chapter 5

B.5.1 Bibliography

Anonymous. 2000. **Riprap Design and Construction Guide.** BC Ministry of Environment, Lands and Parks, Water Management Branch, Victoria, BC. 19p + appendix.

Anonymous. 1999. **Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment**. Fisheries and Oceans Canada, Vancouver, BC., BC Ministry of Environment, Lands and Parks, Victoria, BC. 19p.

B.5.1 Bibliography contd

Anonymous. 1994. **Memorandum of Agreement for the Washington State Departments of Fisheries, Wildlife, and Ecology and the United States Army Corps of Engineers concerning Vegetation and Habitat Management on Flood Control Structures**. Department of the Army, Seattle District, Corps of Engineers, Seattle, WA.

Anonymous. undated. **Issues Regarding Vegetation Management on Levee Embankments**. REMR Technical Note EI-M-1.4. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Chillibeck, B., G. Chislett and G. Norris. 1992. **Land Development Guidelines for the Protection of Aquatic Habitat.** Fisheries and Oceans Canada, Vancouver, BC and BC Ministry of Environment, Lands and Parks, Victoria, BC. 128p. www-heb.pac.dfo-mpo.gc.ca/english/publications.htm.

Johnson, A.W. and J.M. Stypula. 1993. **Guidelines for Bank Stabilization Projects in the Riverine Environments of King County**. King County Department of Public Works, Surface Water Management Division, Seattle, WA. dnr.metrokc.gov/wlr/biostabl/.

B.5.2 Photographic Credits

Chapter Cover		Mark A. Adams
Page 44	Figure 5.2	Mark A. Adams
Page 46	Figure 5.5	Kon Johansen
	Figure 5.6	Rolf W. Sickmuller
Page 49	Figure 5.9	Mark A. Adams
	inset	Mark A. Adams

Chapter 6

B.6.1 Bibliography

Adams, M.A., and I.W. Whyte. 1990. **Fish Habitat Enhancement: A Manual for Freshwater, Estuarine and Marine Habitats.** Fisheries and Oceans Canada, Vancouver, BC. DFO 4474. 330p.

Anonymous. undated. **Northwest Native Plants - Identification and Propagation**. King County Department of Public Works, Surface Water Management Division, Seattle, WA. 37p + appendices.

Browse, P.M. 1988. **Plant Propagation**. Simon and Schuster, Inc., Toronto, ON. 96p.

Link, R. 1999. **Landscaping for Wildlife in the Pacific Northwest**. University of Washington Press, Seattle, WA. 320p.

MacDonald, B. 1989. **Practical Woody Plant Propagation for Nursery Growers**. Timber Press, Portland, OR. 669p.

Vanbianchi, R., M. Stevens, T. Sullivan and S. Hashisaki. 1994. **A Citizen's Guide to Wetland Restoration. Adopt a Beach**. Seattle, WA. 71p.

B.6.2 Photographic Credits

Chapter Cover		Mark A. Adams
Page 56	Figure 6.2	Mark A. Adams
Page 58	Figure 6.4	Mark A. Adams
	Figure 6.5	Mark A. Adams
Page 59	Figure 6.6	Mark A. Adams
Page 60	Figure 6.7	Mark A. Adams
Page 63	Figure 6.8	Mark A. Adams
	Figure 6.9	Myles Hargrove
Page 64	Figure 6.10	
	top	Mark A. Adams
	inset	John Grindon
	bottom	John Grindon
	inset	Mark A. Adams
Page 65	Figure 6.11	
	left	Mark A. Adams
	middle	Bruce Peel
	right	Mark A. Adams
Page 66	Figure 6.12	Mark A. Adams
	Figure 6.13	Mark A. Adams
	inset	Mark A. Adams
Page 67	Figure 6.14	Mark A. Adams
	Figure 6.15	Mark A. Adams
	inset	Mark A. Adams

Appendix C

B.C.1 Bibliography

Alaback, P., J. Antos, T. Goward, K. Lertzman, A. MacKinnon, J. Pojar, R. Pojar, A. Reed, N. Turner and D. Vitt. 1994. **Plants of Coastal British Columbia**. BC Ministry of Forests. J. Pojar and A. MacKinnon (Eds.). Lone Star Publishing, Vancouver, BC. 526p.

Brayshaw, T.C. 1976. **Catkin Bearing Plants (Amentiferae) of British Columbia**. Occasional Papers of the British Columbia Provincial Museum No.18. Province of British Columbia, Victoria, BC. 176p.

Cooke, S.S. (ed.). 1997. **A Field Guide to the Common Wetland Plants of Western Washington and Northwestern Oregon**. Seattle Audubon Society, Seattle, WA. 417p.

Correll, D.S. and H.B. Correll. 1975. **Aquatic and Wetland Plants of Southwestern United States.** 2 Volumes. Stanford University Press, Stanford, CA. 1777p.

Farrar, J.L. 1995. **Trees in Canada**. Canadian Forest Service. Fitzhenry and Whiteside Limited, Markham, ON. 502p.

Hitchcock, C.L., A. Cronquist, M. Ownbey and J.W. Thompson. 1969. **Vascular Plants of the Pacific Northwest**. 5 Volumes. University of Washington Press, Seattle, WA.

Klinka, K., V.J. Krajina, A. Ceska and A.M. Scagel. 1989. **Indicator Plants of Coastal British Columbia**. BC Ministry of Forests. University of British Columbia Press, Vancouver, BC. 288p.

Weinmann, F., M. Boule, K. Brunner, J. Malek and V. Yoshino. 1984. **Wetland Plants of the Pacific Northwest**. U.S. Army Corps of Engineers, Seattle District, Seattle, WA. 85p.

B.C.2 Photographic Credits

Mark A. Adams with the exception of photographs provided by Art McLeod, as follows:
Pages B-9; B-26; B-32 (female cone); B-33 (female cone); B-35 (catkins); B-38; B-48 (berries); and, B-50.

Appendix C: Common Wetland and Riparian Plants

Introduction

The intent of this appendix is to familiarize the reader with common wetland and riparian plants that are frequently used by habitat mitigation and compensation projects. This presentation does not attempt to identify and describe all the plants that occur within coastal wetland and riparian environments, but rather introduce to the reader plants that are characteristic of these environments.

The taxonomy utilized is based on Hitchcock *et al.* (1969). Changes to the scientific names of plants since this publication are presented below.

Osmaronia cerasiformis = *Oemleria cerasiformis*
Populus trichocarpa = *Populus balsamifera* var. *trichocarpa*
Pyrus fusca = *Malus fusca*
Salix lasiandra = *Salix lucida* var. *lasiandra*
Scirpus acutus = *Schoenoplectus acutus*
Scirpus americanus = *Schoenoplectus pungens* var. *longispicatus*
Scirpus cyperinus var. *brachypodus* = *Scirpus atrocinctus*
Scirpus maritimus var. *paludosus* = *Bolboschoenus maritimus* var. *paludosus*
Scirpus validus = *Schoenoplectus tabernaemontani*
Triglochin maritimum = *Triglochin maritima*

The majority of definitions presented in the glossary of plant terms, and the majority of the descriptors presented in the species summaries, including illustrations, are based on Hitchcock *et al*.

Glossary of Plant Terms

acuminate gradually and concavely tapered to a narrow tip or sharp point

adventitious any root or shoot arising from a stem that otherwise would not be expected (e.g. roots and shoots that emerge as a result of burial of the stem)

anthesis the period when a flower is fully expanded and functional

apical at the apex of the tip

auricle a small projecting lobe or appendage such as at the base of the petiole or blade

awn a slender bristle

bract a reduced or modified leaf associated with a flower or an inflorescence; it is not part of the flower or inflorescence

bractlet a small bract; a bract that is borne on a petiole rather than subtending it

callus the firm, thickened base of the lemma

calyx the sepals of a flower, collectively

capsule a dry dehiscent fruit composed of more than 1 carpel

carpel a fertile leaf bearing undeveloped seed(s)

catkin	a dense compact or elongated inflorescence bearing many small naked or apetalous flowers
channeled	marked with one or more deep, longitudinal grooves
cone	a cluster of fertile leaves or associated scales on an axis
cordate	heart-shaped with a notch at the base
dehiscent	opening at maturity to release or expose contents (e.g. seeds)
distal	toward or at the tip, or at the furthest distance away
drupe	a fleshy fruit that encloses a stony seed (e.g. cherries)
ellipsoid	elliptic in longitudinal section and circular in cross section (3-dimensional descriptor)
emergent	emerging or coming out from; typically with reference to marsh plants that emerge and stand above the water's surface
flexuous	displaying a zig-zag habit
fruit	a ripened ovary, together with any other contiguous structures that ripen with it
glabrous	smooth; without hairs or glands
glume	one of a pair of bracts at the base of a grass spikelet that does not subtend the spikelet
habit	the general appearance or manner of growth of a plant
heterophyllous	displaying more than one shape of leaf
inflorescence	a cluster or grouping of flowers
lacerate	with an irregularly jagged margin
leader	the terminal (i.e. top) shoot of a tree
leaf axil	the point of the angle formed by the leaf or petiole with the stem
lemma	one of the pair of bracts (lemma and palea) which generally subtends individual flowers in grass spikelets
lenticel	a slightly raised area in the bark of a stem or root that displays a porous texture
lenticular	shaped like a double convex lens
ligule	the appendage on the inner (upper) side of the leaf at the junction of the blade and sheath of grasses
necrotic	a plant organ displaying dead tissue
node	the place on the stem to which leaves are, or have been, attached
obovate	like ovate, but larger toward the distal end
obtuse	blunt; with the sides coming together at an angle of more than 90°
ovate	shaped like the longitudinal section through a hen's egg (1-dimensional descriptor)

ovoid	shaped like a hen's egg (3-dimensional descriptor)
palea	one of the pair of bracts (lemma and palea) which generally subtends individual flowers in grass spikelets
pedicel	the stalk of a single flower in an inflorescence
peduncle	the stalk of an inflorescence or of a solitary flower
perianth	the sepals and petals of a flower collectively
perigynium	a special bract that encloses the achene in *Carex*
petal	a member of the internal set of floral leaves that are usually white or colored
petiole	a leaf stalk
pith	spongy tissue in the centre of the stem or trunk of some woody plants
prostrate	flat on the ground
pubescent	bearing small hairs
reticulate	displaying a matrix or grid pattern
rhizome	a creeping underground stem
rhombic	having the figure of a rhomb, a quadrilateral figure whose sides are equal and opposite sides parallel, as in a diamond (3-dimensional descriptor)
scabrous	rough to the touch, due to the structure of the epidermis or to the presence of short, stiff hairs
scale	any small, thin or flat structure
sepal	a member of the external set of floral leaves that are usually greenish and more or less leafy in texture
septum	a partition within the hollow leaf or stem of some aquatic and emergent plants (pl. septa)
sessile	attached directly by the base, without a stalk, such as a leaf without a petiole or a flower without a pedicel
spike/spikelet	a more or less elongated unbranched inflorescence with sessile or subsessile flowers
stipule	one of a pair of basal appendages found on many leaves
stolon	an elongated, creeping stem on the surface of the ground
stoma	a minute opening in the epidermis of leaves through which water vapour passes (pl. stomata)
style	slender stalk which typically connects the stigma to the ovary
tepal	a sepal or petal, or a member of an undifferentiated perianth
trigonous	with three angles
whorl	a ring of 3 or more similar structures radiating from a node or common point

Plant List

Carex aquatilis
C. sitchensis
SCIENTIFIC NAME

Water Sedge
Sitka Sedge
COMMON NAME

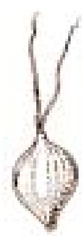
Water sedge is characterized by 30 to 100 cm long stems borne singly or few together on stout, well developed rhizomes. The leaves are flat, long and 2 to 7 mm in width. Sitka sedge is similar to water sedge; it has coarser, stouter and more densely clustered stems. Rhizomes are short or absent with stems up to 2 m in length. The leaves are up to 1 cm in width.

The inflorescence of water sedge is characterized by 3 to 7 well spaced, cylindrical spikes, 1.5 to 5 cm in length. The terminal spike is typically male, while the other spikes are either entirely female or both male (upper portion) and female (lower portion). All the spikes are sessile or nearly so. The bracts subtend the terminal spike, the lowest one elongate and leaf-like, ranging in length from 7 to 25 cm. The perigynium is elliptic to obovate, more or less strongly flattened, with well developed marginal nerves. It is 2 to 3.3 mm in length, including the short (0.1-0.3 mm) beak. Each perigynium is accompanied by a scale reddish-brown to purplish-black in colour with a pale midrib. The scale is generally narrower and minutely shorter to longer than the perigynium. The lenticular achene is 1.2 to 1.5 mm in length; it is distinctly shorter and typically narrower than the perigynial cavity.

Sitka sedge displays 2 to 3 terminal male spikes. In comparison to water sedge, the spikes are more elongate and range from 3 to 10 cm in length. The spikes, in particular the lower ones, are generally more or less nodding on slender peduncles that range from 3 to 10 cm in length.

Both water sedge and Sitka sedge commonly occur within fens, shrub swamps and tidal and non-tidal fresh marshes. They can withstand longer periods of inundation than most other *Carex* of fresh marshes; as a result, it may be found along the margins of sloughs as near-monospecific stands. Within non-tidal fresh marshes, common community associates include beaked sedge, bluejoint reedgrass and reed canary grass.

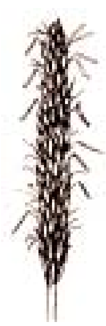
C. aquatilis



perigynium

inflorescence for water sedge

inflorescence for Sitka sedge



male spike

female spike

Carex lyngbyei
SCIENTIFIC NAME

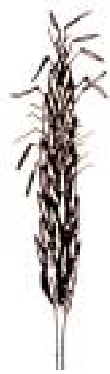
Lyngby's Sedge
COMMON NAME

The 15 to 100 cm tall stems emerge singly or in small clusters from well developed creeping rhizomes. The leaves are flat, mostly 2 to 6 mm in width, and are typically shorter than the stem.

The upper 1 to 2 floral spikes are male, while the lower 2 to 6 spikes are entirely female or part male (upper portion) and female (lower portion). The upper spikes are somewhat erect, being borne on short peduncles, while lower spikes, borne on long peduncles, typically droop or nod. The perigynium is elliptic to elliptic-ovate (egg-shaped), leathery and thick-walled with prominent nerves along its margins and somewhat obscure nerves on its faces; it is 2.2 to 3.5 mm in length, with 2 stigmas emerging from its small beak. The lenticular achene is 1.6 to 2.2 mm in length. Light to dark brown sharp tipped scales, with a pale midrib, are narrower and longer than the perigynia.

Lyngby's sedge is often the dominant species of tidal low salinity brackish and fresh marshes. It often occurs as expansive near-monospecific stands. Within low salinity brackish environments, common community associates include American three-square, Baltic rush, saltmarsh bulrush and seaside arrowgrass. Within fresh environments, common community associates include softstem bulrush, hardstem bulrush, creeping spike rush, jointed rush, creeping bentgrass and broadleaved cattail. A common associate within near-monospecific stands is lilaeopsis (*Lilaeopsis occidentalis*); this diminutive plant occurs within the 'understory' of such stands. Lyngby's sedge occurs throughout coastal British Columbia.

Due to its high net annual production of biomass (per unit area), and its tendency to be a dominant species within estuarine environments, it is considered to be a critical component of the productive capacity of these environments for fish and wildlife.



male spike

female spike

habit

perigynium

Carex obnupta
SCIENTIFIC NAME

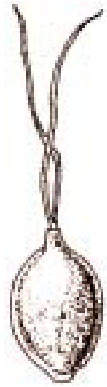
Slough Sedge
COMMON NAME

The general habit of the plant is as dense tufts of stems 60 to 150 cm in length. The coarse, firm leaves are flat or channelized, 3 to 10 mm in width and shorter than the stems. The plant possesses long, stout, creeping rhizomes.

The upper 1 to 3 floral spikes are male, while the lower 2 to 5 spikes are entirely female or part male (upper portion) and female (lower portion). The spikes are sessile or borne on short peduncles. The perigynium is elliptic, leathery and thick walled with prominent nerves along its margins and without nerves on its faces; it is 2.4 to 3.1 mm in length, with 2 stigmas emerging from its small beak. The lenticular achene is 1.9 to 2.4 mm in length and almost fills the perigynium. Purplish-black sharp tipped scales, each with a pale midrib, extend beyond the perigynia.

Slough sedge is common within mid to high elevation tidal fresh marshes and shallow non-tidal fresh marshes. It is a conspicuous groundcover within tidal and non-tidal fresh swamps. It occurs occasionally within low salinity brackish tidal swamps where inundation is infrequent. In contrast to many other wetland species, it is evergreen, retaining the majority of its leaves through the winter. Slough sedge occurs within coastal British Columbia south of latitude 55° N.

Common community associates within fresh marshes include small-fruited bulrush, woolly bulrush, bluejoint reedgrass, reed canary grass, beaked sedge and other sedge species. A common community associate within fresh swamps is small-fruited bulrush.



perigynium

achene

female spike

habit

Carex rostrata
SCIENTIFIC NAME

Beaked Sedge
COMMON NAME

The stems, 50 to 120 cm in height, arise singly or as clusters from stout, elongate creeping rhizomes. Leaves are distributed along the entire length of the stem; the upper leaves often extend beyond the height of the stem. The leaves are robust, distinctively yellowish-green, generally flat (often with a channel at the base) and up to 12 mm in width.

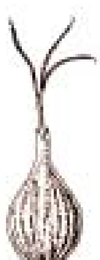
The upper 2 to 4 male floral spikes are 2 to 6 cm in length, with the upper and lower spikes peduncled and sessile, respectively. The lower 2 to 5 female floral spikes are 2 to 10 cm in length and up to 1.5 cm in width, cylindrical to oblong, sessile or nearly so. Intermediate spikes occasionally sustain both male (upper portion) and female (lower portion) flowers. The trigonous achene, 1.3 to 2 mm in length, is contained within an inflated, elliptic-ovate (egg-shaped), membraned perigynium 4 to 7 mm in length, the end abruptly contracted into a conspicuous beak. The style is persistent, bony, becoming strongly flexuous or contorted as the achene matures. Three (3) stigmas append the style. The achenes are accompanied by brown scales that are typically both shorter and narrower than the achenes.

This sedge does not occur within tidal salt or brackish marshes. It is, however, one of the most common sedges of fresh marshes in British Columbia. It often occurs within tidal fresh marshes as expansive, near-monospecific stands. It occupies the mid to high elevations of these marshes. Beaked sedge is common within fresh marshes of lake margins and low elevation bogs. It also occurs within the most saturated portions of wet meadows. Except for the Queen Charlotte Islands, it occurs throughout British Columbia.

Common community associates within fresh marshes include water sedge, slough sedge, bluejoint reedgrass, reed canary grass and broadleaved cattail. Within wet meadows, common community associates include reed canary grass, creeping bentgrass, woolly bulrush, small-fruited bulrush and soft rush.

habit

female spike



perigynium

achenes within perigynia

Scirpus acutus
S. validus
SCIENTIFIC NAMES

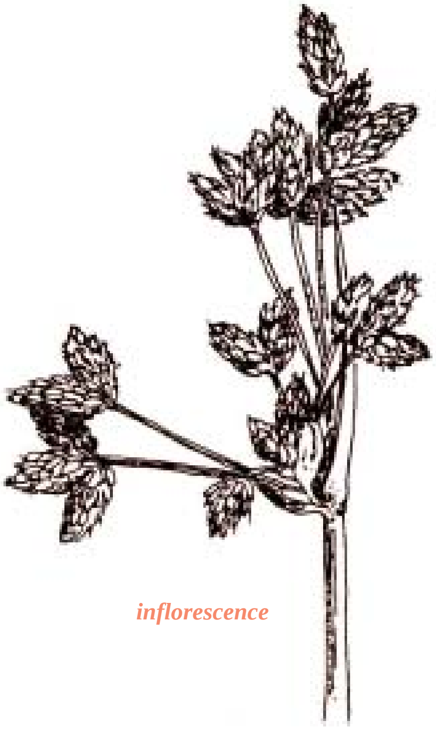
Hardstem Bulrush
Softstem Bulrush
COMMON NAMES

Both hardstem bulrush and softstem bulrush attain heights of 1 to 3 m. The plants are characterized by large woody rhizomes and round stems that measure 1 to 3 cm in diameter at the base. The common names refer to the ease with which one can crush the stem between one's fingers. The leaves are reduced and are restricted to the base of the plants.

Terminal clusters of approximately 10 spikelets are borne on short and long peduncles on hardstem and softstem bulrush, respectively; the inflorescence of hardstem bulrush is more compact than that of softstem bulrush. The spikelets of hardstem bulrush are longer (8 to 15 mm) than those of softstem bulrush (to 10 mm). A narrow bract 3 to 4 cm in length subtends the inflorescence in both species.

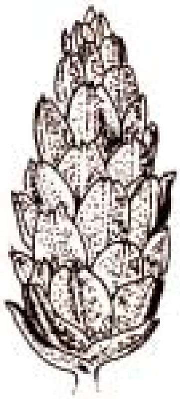
The achenes of both species are approximately 2 to 2.5 mm in length. They are elliptic-ovate (egg-shaped) and have a distinct point (stylar apiculus). Bristles, emerging from the base of the achenes, are equal to or exceed the length of the achene. The achenes are wrapped by brownish to greyish scales, completely in hardstem bulrush and partially in softstem bulrush.

S. acutus

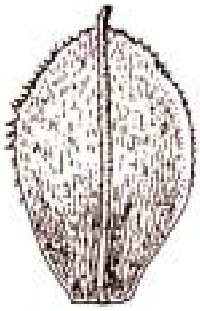


S. acutus

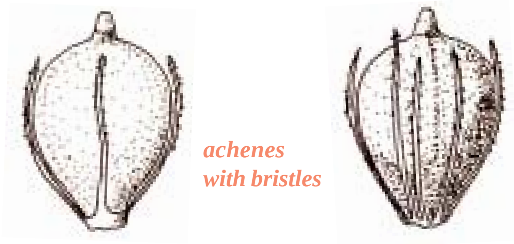
inflorescence



spikelet



scale



achenes with bristles

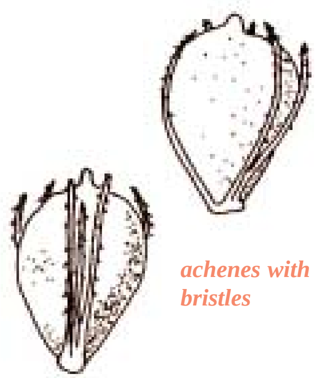
S. validus

Both species occur within fresh marshes along the margins of lakes to depths up to 1 m. Within tidal fresh and brackish marshes, they may be found within low elevation, well-drained marshes, or within high elevation, poorly-drained marshes. Both species often form expansive, near-monospecific stands.

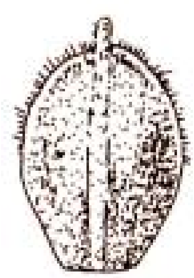
The two species are often found together throughout British Columbia. A common community associate within fresh marshes of lake margins is broadleaved cattail. Within low elevation tidal fresh marshes, common community associates include creeping spike rush and Lyngby's sedge. Within low elevation brackish marshes, common community associates include Lyngby's sedge, American threesquare, saltmarsh bulrush and seaside arrowgrass. Within high elevation tidal fresh marshes, where drainage is poor, common community associates include broadleaved cattail, small-fruited bulrush and jointed rush.

general habit of both species

spikelet



achenes with bristles



scale

S. validus

inflorescence

Scirpus americanus

SCIENTIFIC NAME

American Threesquare

COMMON NAME

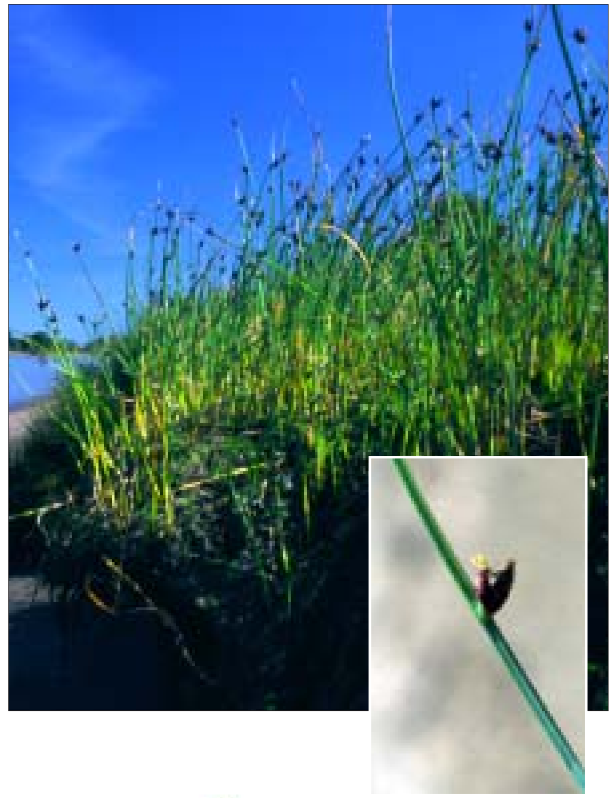
The stems of American threesquare emerge singly or in small clusters from long, stout rhizomes. The stems are triangular with flat to slightly concave or convex sides. Stem height ranges between 15 and 150 cm. Several leaves that start at or near the stem base range from 2 to 4 mm in width and 20 to 100 cm in length.

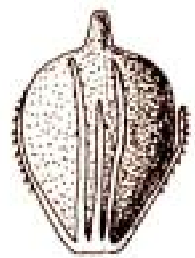
One (1) to 6 floral spikelets, 7 to 20 mm in length, occur in a sessile compact cluster. The cluster is subtended by a prominent bract, 3 to 10 cm in length, which appears to be a continuation of the stem. The achene is dark brown and lens shaped with a prominent tip; it is 2 to 3 mm long and surrounded by 2 to 6 bristles equal to or shorter than the achene in length. The scales are brown to blackish purple, with a firm midrib extended as a short awn from the cleft tip.

American threesquare often occurs as expansive, near-monospecific stands within tidal brackish marshes. It also occurs as scattered individuals or small patches within tidal fresh and salt marshes. It typically occupies the low to middle elevations of tidal marshes. American threesquare occurs within non-tidal fresh marshes along the shallow margins of lakes. It occurs in British Columbia generally south of latitude 53° N.

Common community associates within tidal brackish marshes are Lyngby's sedge, Baltic rush, saltmarsh bulrush, softstem bulrush, hardstem bulrush and seaside arrowgrass.

American threesquare is an important component of delta front marshes of the Fraser River estuary. The rhizomes are extensively grazed by resident and migrating geese.





achene with bristles

spikelet cluster

habit

Scirpus cyperinus var. *brachypodus*

SCIENTIFIC NAME

Woolly Bulrush

COMMON NAME

The stems of woolly bulrush, 80 to 150 cm in height, are grouped together as a distinctive tuft. Unlike many other *Scirpus* species, it does not possess rhizomes. The leaves are flat, grass-like (not channelized as in many *Carex* species), up to 6 mm in width, and distributed along the entire length of the stem.

The spikelets are small (3 to 8 mm in length) and numerous, being borne on short, slender peduncles within a terminal inflorescence. Numerous bracts, up to 10 cm in length, subtend the inflorescence. Scales, approximately 1.5 mm in length, are pale green to greenish-black with distinctive fine, red-brown longitudinal lines. Achenes, typically less than 1 mm in length, are trigonous. Six (6) bristles, longer than both achenes and scales, emerge from the base of each achene; these tawny, flexuous bristles give the spikelets their woolly appearance.

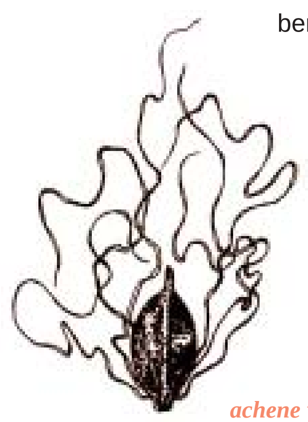
Woolly bulrush occurs at mid to high elevations within tidal fresh marshes. Its tufted habit prevents it from establishing near-monospecific stands; other species inhabit the spaces between individual tufts. Woolly bulrush is often a dominant species within wet meadows where saturated soils persist. It is a conspicuous component of marshes along the margins of streams, rivers and lakes.

Common community associates include small-fruited bulrush, soft rush, reed canary grass, creeping bentgrass, beaked sedge and slough sedge.

general habit

habit of inflorescence

spikelet



achene with flexuous bristles

Scirpus maritimus var. *paludosus*

SCIENTIFIC NAME

Saltmarsh Bulrush

COMMON NAME

The triangular stems of saltmarsh bulrush achieve heights of 20 to 150 cm. The leaves are up to 1 cm in width and are well distributed along the entire length of the stem. The stout rhizomes often bear well-defined tubers.

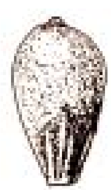
The floral spikelets typically occur in a sessile, compact, terminal cluster. Subsidiary clusters of spikelets (5 to 10) sometimes occur on short peduncles (to 5 cm long) emerging from the basal cluster. Spikelets are 1.2 to 2 cm in length and 1 cm in width, and number from 3 to 20 per cluster. Several bracts of up to 10 cm in length extend from the base of the spikelets. The lenticular achenes are approximately 3 mm in length and surrounded by 2 to 6 barbed bristles up to 1.5 mm in length. The scales are tan to dark brown with a midvein extended into a short awn that emerges from a notch at the end of each scale.

Saltmarsh bulrush occurs within tidal brackish marshes, often as expansive near-monospecific stands. It typically occupies the low to mid elevations of these marshes. Common community associates include Lyngby's sedge, American threesquare, softstem bulrush, hardstem bulrush and seaside arrowgrass. Saltmarsh bulrush also occurs within inland fresh and alkali marshes. It occurs within British Columbia generally south of latitude 53° N.

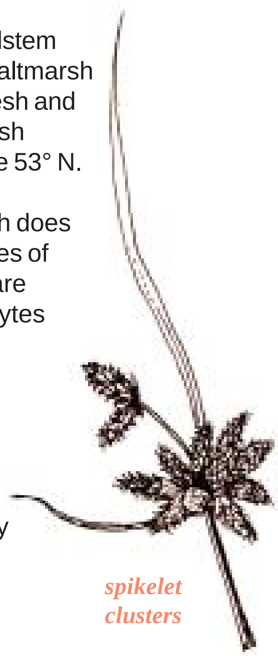
Despite its name, saltmarsh bulrush does not typically inhabit tidal salt marshes of British Columbia. These marshes are inhabited by more classic halophytes such as pickleweed and saltgrass.

As for American threesquare, saltmarsh bulrush is an important component of delta front marshes of the Fraser River estuary. The tubers and rhizomes are extensively grazed by resident and migrating geese.

spikelet



achene with bristles



spikelet clusters

habit

Scirpus microcarpus
SCIENTIFIC NAME

Small-fruited Bulrush
COMMON NAME

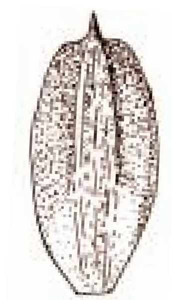
Distinctly triangular stems, 60 to 150 cm in height, arise from long, stout rhizomes. The channelized leaves are 1 to 2 cm in width and are borne by the stem throughout its length.

The inflorescence consists of several spreading stalks terminally adorned with clusters of small spikelets. Distinctive bracts occur at the base of the inflorescence. The lenticular achenes, approximately 1 mm in length, characterized by a distinctive stylar apiculus, are adorned by 4 to 6 bristles that slightly surpass the length of the achene. The scales are approximately 1.5 mm in length, greenish-black with a pale green mid-rib.

Small-fruited bulrush occurs within fresh wetlands. It occurs sporadically or as relatively small monospecific patches within the high elevation zone of tidal fresh marshes. It occurs within the understory of open canopy tidal and riparian (floodplain) swamps. Small-fruited bulrush occurs within wet meadows and along the margins of shallow ponds. It prospers within saturated soils, but does not appear to withstand either extended or frequent (e.g. inundated twice daily by tides) periods of inundation.

Common community associates within tidal fresh marshes include broadleaved cattail, softstem bulrush, hardstem bulrush and jointed rush. Within fresh swamps, it is often found with slough sedge. Common community associates within wet meadows include reed canary grass, woolly bulrush, beaked sedge, soft rush and creeping bentgrass.

habit



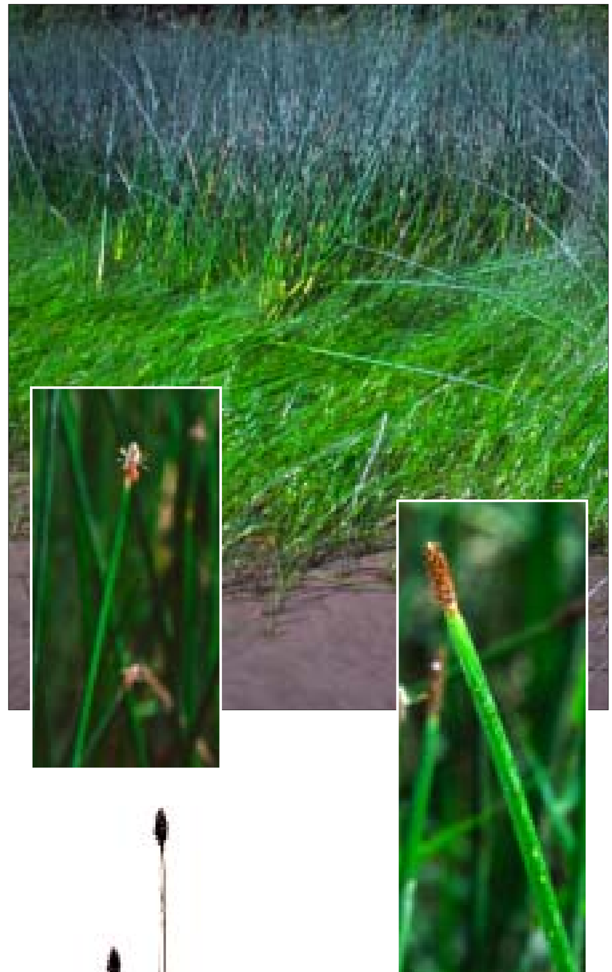
scale

achene with bristles

spikelet

Eleocharis palustris
SCIENTIFIC NAME

Creeping Spike Rush
COMMON NAME



The slender to stout stems of creeping spike rush achieve heights of 10 to 100 cm; they are round to oval in cross section. The stems emerge individually or in small clusters along creeping rhizomes. The leaves are reduced, occurring as sheaths at the base of the stem.

A solitary floral spikelet 5 to 23 mm in length occurs at the top of the stem. The achenes are lens shaped, 1 to 1.5 mm in length, and are adorned with a terminal conical tubercle. Four (4) bristles surround and exceed the achene in length.

Creeping spike rush is a conspicuous component of low elevation tidal fresh and low salinity brackish marshes, where it often occurs as a narrow, linear, near-monospecific stand. It is also common throughout British Columbia within a variety of inland fresh wetlands.

Within tidal marshes, common community associates include softstem bulrush, hardstem bulrush, Lyngby's sedge and jointed rush.

achene with tubercle and bristles

robust spike morphology

slender spike morphology

tall habit

short habit

Juncus articulatus

SCIENTIFIC NAME

Jointed Rush

COMMON NAME

The stems of jointed rush are 15 to 30 cm in length. Larger plants are conspicuously tufted, with stems emerging from short rhizomes or the lower nodes (adventitiously) of a primary stem. The leaves occur throughout the entire length of the stem; they possess complete septa and rounded conspicuous auricles.

Numerous floral heads, consisting of 6 to 12 flowers, on mostly spreading branches, comprise the terminal inflorescence. The involucral bract is shorter than the 2 to 15 cm long inflorescence. The petals and sepals of each flower appear superficially to be scales. They are typically brown and 2.5 to 3 mm in length. The dry fruit or capsule is conic-ovoid, rather uniformly tapered to the top, and somewhat triangular with distinct ridges. The capsule is longer than the perianth. The seeds are up to 0.5 mm in length, ellipsoid, sharply tipped, and lightly striated longitudinally.

capsule with perianth

Jointed rush appears within mid to low elevations of tidal fresh marshes, where it often forms isolated monospecific patches. It functions as a pioneer species within recently disturbed mid to low elevation tidal fresh marshes; it will colonize and dominate the disturbed area for several seasons before being displaced by species typically dominant at that elevation. It occurs sporadically within poorly drained high elevation portions of tidal fresh marshes. It is often found within tidal brackish marshes where fresh seeps or discharges occur (e.g. stormwater outfalls). It occurs sporadically along the margins of streams and lakes. Jointed rush occurs throughout coastal and southern inland portions of British Columbia.

seed

Common community associates within low to mid elevation tidal fresh marshes include Lyngby's sedge and creeping spike rush. Within high elevation tidal fresh marshes, where drainage is poor, common community associates include softstem bulrush, hardstem bulrush, broadleaved cattail and small-fruited bulrush.

base of stem displaying auricle

habit

Juncus balticus

SCIENTIFIC NAME

Baltic Rush

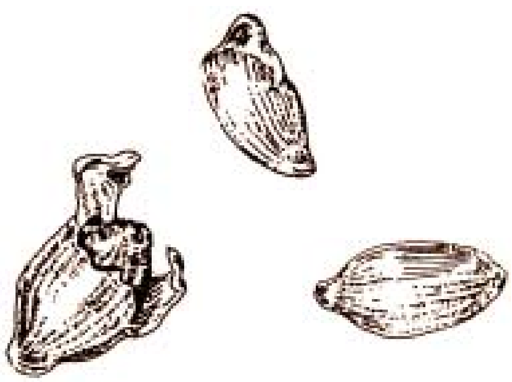
COMMON NAME

The cylindrical stems of Baltic rush emerge from stout, spreading rhizomes. The stems are 15 to 80 cm in height and 1.5 to 4 mm wide at the base. If present, the leaves are reduced, occurring as sheaths at the base of the stem.

The inflorescence is borne laterally off the stem; it is subtended by a prominent bract 5 to 20 cm in length that appears to be a continuation of the stem. The petals and sepals of each flower, collectively known as the perianth, appear superficially to be scales. They are 4 to 5 mm in length and green to brown in colour with a green midstreak. The dry fruit, a capsule, is ovoid and shorter in length than the perianth. Seeds are approximately 0.6 mm in length, ovoid-ellipsoid, finely reticulate, with minute tips.

Baltic rush often occurs as near-monospecific stands at mid to high elevations within tidal brackish and fresh marshes. It prefers well-draining substrates, with stands often forming discernable hummocks. Inland, Baltic rush may be found along the margins of lakes and within bogs.

Lyngby's sedge is a common community associate within tidal fresh marshes. Lyngby's sedge and American threesquare are common community associates within tidal brackish marshes.



seeds with and without membranous coat

perianth encompassing capsules

habit

inflorescence

Juncus effusus

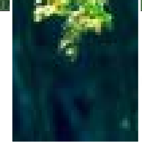
SCIENTIFIC NAME

Soft Rush

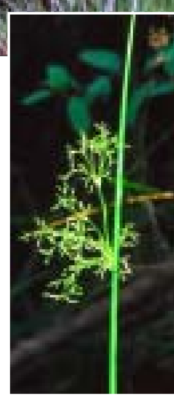
COMMON NAME

This strongly tufted plant is characterized by cylindrical hollow stems and stout rhizomes. The stems are 20 to 100 cm in height and 1.5 to 3 mm in diameter. Leaves are reduced, occurring as brown sheaths at the base of each stem.

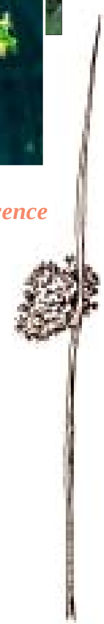
The inflorescence is borne laterally off the stem; it is subtended by a prominent bract, 5 to 20 cm long, which appears to be a continuation of the stem. The petals and sepals of each flower, collectively known as the perianth, appear superficially to be scales. They are green to brown in colour, and 2.5 to 3.5 mm in length. The dry fruit, known as a capsule, is slightly shorter or equal in length to the perianth. The capsule is obovate, slightly triangular with distinct ridges and blunt near the top. Seeds are approximately 0.4 mm in length, ellipsoid, finely ridged, with minute tips.



compact inflorescence



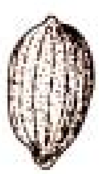
loose inflorescence



Soft rush is a highly variable plant, displaying numerous distinct inflorescence morphologies. Nine varieties have been identified within North America, four of which are known in the Pacific Northwest.

Soft rush may be found almost wherever saturated soils persist. It does not appear to withstand either long or frequent (e.g. inundated twice daily by tides) periods of inundation. Soft rush is restricted to fresh marshes. Within tidal fresh marshes, it is found sporadically at high elevations. Despite its tufted habitat, its rhizomatous nature allows it to establish near-monospecific stands within wet meadows and shallow fresh marshes. Soft rush has been identified as an agricultural pest within cultivated wet fields. It is common within roadside ditches, drainage swales and recently disturbed wet sites. It is found throughout British Columbia.

Common community associates within wet meadows and shallow fresh marshes include bentgrass, woolly bulrush, reed canary grass, small-fruited bulrush and beaked sedge.



seed

capsule with perianth

habit

Agrostis stolonifera
A. exarata
SCIENTIFIC NAMES

Creeping Bentgrass
Spike Bentgrass
COMMON NAMES

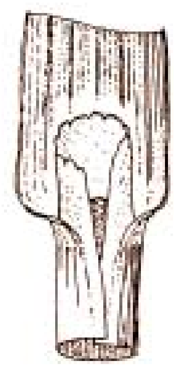
Creeping bentgrass has both stolons and rhizomes. It may display either an erect or prostrate and stoloniferous habit. The stems are 50 to 120 cm in height. The ligules are truncate to obtuse, with those of the upper stem leaves 3 to 6 mm in length. The leaves may be flat or folded and 2 to 10 mm in length.

Spike bentgrass typically displays a tufted habit, with the erect stems closely gathered together. The stems sometime bend and root from basal nodes. The stems achieve heights of 20 to 120 cm. Short rhizomes often extend outwards from the tuft. The ligules are similar in morphology to those of creeping bentgrass, ranging in length from 3 to 8 mm. The leaves are flat and typically scabrous.

A. stolonifera

A. stolonifera

habit



blade, sheath and ligule

glumes

A. exarata

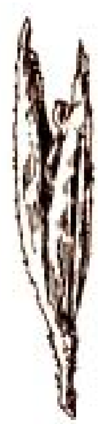
The inflorescence is similar for both species. It is 5 to 30 cm in length, narrow and spike-like to somewhat open, and purplish in colour. The branches of the inflorescence in creeping bentgrass are appressed to ascending, while the branches in spike bentgrass are always strongly ascending to erect. The branches of both species bear spikelets almost to the base. The glumes are small (2.5 to 3 mm in *A. stolonifera*; 2.5 to 4.5 mm in *A. exarata*). The lemmas in both species are shorter than the glumes, ranging in length from 1.5 to 2.5 mm. Creeping bentgrass is typically awnless, while spike bentgrass may be awned or awnless. The awns, if present, are up to 5 mm in length.

Creeping bentgrass is a non-native (European origin) species that has become extensively naturalized within southwestern British Columbia. It is commonly utilized for pastures and lawns. Spike bentgrass is a native species. Both species inhabit the upper elevations of tidal brackish (low salinity) and fresh marshes.

There are several other bentgrass species that may be found within tidal fresh and brackish marshes, specifically colonial bentgrass (*A. capillaris*), redtop (*A. gigantea*), Oregon bentgrass (*A. oregonensis*) and rough bentgrass (*A. scabra*).

blade, sheath and ligule

habit



glumes

Glyceria elata
G. grandis
SCIENTIFIC NAMES

Tall Mannagrass
Reed Mannagrass
COMMON NAMES

G. elata

Both mannagrass species are strongly rhizomatous plants, with stems emerging singly from a rhizome in tall mannagrass, and multiple stems emerging from a rhizome in reed mannagrass. Tall mannagrass grows to heights of 100 to 150 cm, while reed mannagrass reaches 90 to 160 cm in height.

The leaves of both species are flat, with blade widths typically 6 to 10 mm and 6 to 15 mm in width for tall and reed mannagrass, respectively. In tall mannagrass, the sheaths are closed near the top and rough to the touch when rubbed towards the stem. In reed mannagrass, the sheaths are smooth and closed completely or open to 1 cm. The ligules are hairy, obtuse, and are typically 3 to 6 mm in length for tall mannagrass. For reed mannagrass, the ligules are 4 to 9 mm length, smooth and display a pointed tip.

The inflorescence of tall mannagrass is loose, open and spreading. It ranges in length from 15 to 25 cm. The spikelets are ovate and 4 to 8 flowered. The glumes are of unequal length, the first approximately 1 mm and the second approximately 0.5 mm. They are irregularly margined (appearing torn), often with small hairs. The lemmas are 2 mm in length, 7 nerved and appearing slightly torn. The paleas are minutely cleft at the tip.

G. elata

habit

glumes

The inflorescence of reed mannagrass is loose, open and spreading with numerous branches. It ranges in length from 20 to 35 cm. The spikelets are somewhat loose, slightly flattened, oblong and 4 to 7 flowered. The glumes are of unequal length, the first approximately 1.5 to 2 mm and the second approximately 0.7 to 1 mm. They are irregularly margined, often with small hairs. The lemmas are 2 to 3 mm in length, 7 nerved, purplish and slightly torn looking at the blunt tip. The paleas are abruptly notched and sometimes appear torn at the tip.

Both grasses may be observed within shallow non-tidal fresh marshes and wet meadows, and high elevation tidal fresh and low salinity brackish tidal marshes.

habit

G. grandis

glumes

Phalaris arundinacea

SCIENTIFIC NAME

Reed Canary Grass

COMMON NAME

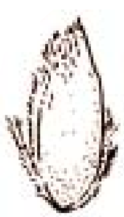
This strongly rhizomatous grass grows to heights of 70 to 140 cm. The stem is hollow and up to 1 cm in diameter. The leaves are flat, 7 to 20 mm in width and up to 30 cm in length. Ligules are 4 to 10 mm in length, obtuse, lacerate and turned backwards.

The inflorescence is typically 8 to 15 cm in length, compact, with the branches spreading only at anthesis. The spikelets consist of groups of 3 flowers. The glumes are slightly unequal in length (4.5 to 5 mm), 3 nerved and minutely hairy. The fertile lemma is 3 to 4.5 mm in length and near smooth with 5 inconspicuous nerves. The palea is shorter than the lemma.

Reed canary grass inhabits a wide range of fresh wetland types. It thrives where saturated soil conditions persist without extended periods of standing water. It is also capable of establishing vigorous stands within seasonally flooded environments. Its ability to tolerate a wide range of inundation regimes within non-tidal fresh wetlands confers it a competitive advantage over other plant species, allowing it to persist as near-monospecific stands.

Reed canary grass often inhabits the highest elevations of tidal fresh marshes. It is a dominant plant of the banks of agricultural sloughs, highway ditches, dikes and other linear public works right-of-ways characterized by wet soils and frequent disturbance (e.g. mowing). It is also a dominant species within wet meadows.

blade, ligule and sheath



lemma

glumes

base of stem displaying rhizomes and roots

inflorescence

Calamagrostis canadensis

SCIENTIFIC NAME

Bluejoint Reedgrass

COMMON NAME

This strongly rhizomatous grass grows to 1.2 m in height. The stems are smooth. The ligules are delicately membranous, 3 to 8 mm in length, and strongly lacerate on all but the basal leaves. The leaves are typically flat and 3 to 8 mm in width.

The inflorescence is usually open, nodding and 10 to 25 cm in length. It is sometimes very narrow, approximately 1.5 cm across at maturity. The glumes are purplish in colour when mature, and range in length from 2.5 to 6 mm. They are slenderly to gradually acuminate to abruptly acute and usually scabrous, always so on the keel. The lemmas are shorter than the glumes, membranous and papery, and plainly to obscurely nerved above. The straight, slender awns are attached from below the midlength to the top of the lemma. Numerous callus hairs adorn the spikelet; they are at least 3/4 the length of the lemma.

Bluejoint reedgrass inhabits a variety of wetlands. It occurs sporadically within tidal fresh marshes. It establishes near-monospecific stands within non-tidal wetlands such as wet meadows, marshes and fens. It is a common inhabitant of the fringes of streams, rivers and lakes. Common community associates include water sedge, beaked sedge, slough sedge and hardhack. Within fens, it is often found together with Pacific crabapple and willows.

habit

glumes

lemma

Distichlis spicata

SCIENTIFIC NAME

Saltgrass

COMMON NAME

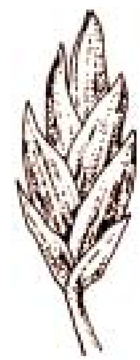
This rhizomatous grass grows up to 40 cm in height. In contrast to many other grasses, its stems are solid. The leaves are bilaterally symmetrical, stiff, sharp-pointed and 2 to 4 mm in width. Auricles are not present on the leaves; the ligule is short (to 0.5 mm in length) and fringed with hairs.

Male and female flowers occur on separate plants; the inflorescence is small and compact. The pedicels of the spikelets are typically not evident, with the male and female glumes 2 to 2.5 mm and 3 to 3.5 mm in length, respectively. The lemmas are unawned, hardened, 4.5 to 6 mm in length, with 9 to 11 convergent obscure nerves.

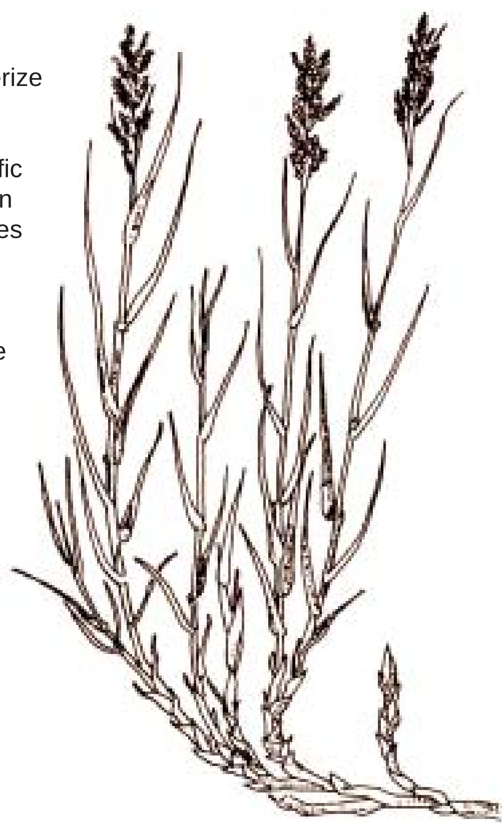
Saltgrass inhabits low to high elevations within salt marshes. It regulates its internal salt content by excreting salt via special cells in its leaves. This ability to regulate salt allows it to inhabit hypersaline soils, such as those that characterize salt pans within high elevation salt marshes.

Saltgrass often occurs as a dense monospecific stand, especially at high elevations. A common community associate within mixed communities is pickleweed.

A closely related species, *Distichlis stricta*, inhabits the margins of alkaline ponds, alkaline flats, and sandy lake shores within inland environments.



male glumes



blade, sheath and ligule

habit

female glumes

Salicornia virginica
S. europaea
SCIENTIFIC NAMES

Perennial Pickleweed
Annual Pickleweed
COMMON NAMES


S. virginica

Salicornia virginica is a perennial pickleweed that possesses distinctive, jointed, fleshy stems up to 1 m in length. The stems may be prostrate, ascending or erect in habit. The leaves are extremely reduced, occurring as small scales. New growth is succulent and may take on a reddish tinge. In winter, most of the succulent growth is lost, leaving only the woody perennial stems.

Numerous erect flowering stems, approximately 5 to 30 cm in length, are distinguished by their brown purplish colour and the 1 to 4 cm long flowering spikes. The tiny yellow flowers are clustered at the tips of the stems, emerging from depressions at the joints.

Pickleweed is the most common plant within low elevation salt marshes. It often forms dense, monospecific mats up to 20 cm thick.

A community associate is often an annual species of pickleweed, *S. europaea* (*S. herbacea*). This annual pickleweed does not possess rhizomes or woody stems. It is characterized by an erect stem habit. *S. rubra* is an inland species that inhabits moist saline and alkaline soils. Like *S. europaea, S. rubra* is an annual species.

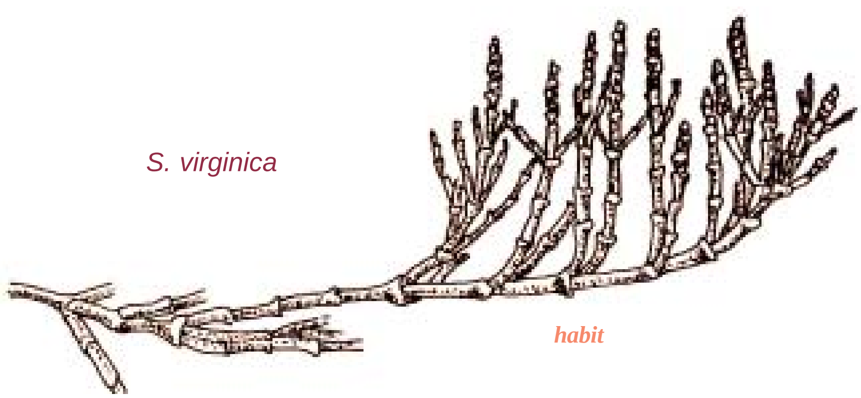
Other common community associates of perennial pickleweed include saltgrass and arrowgrass.


habit


inflorescence

S. europaea

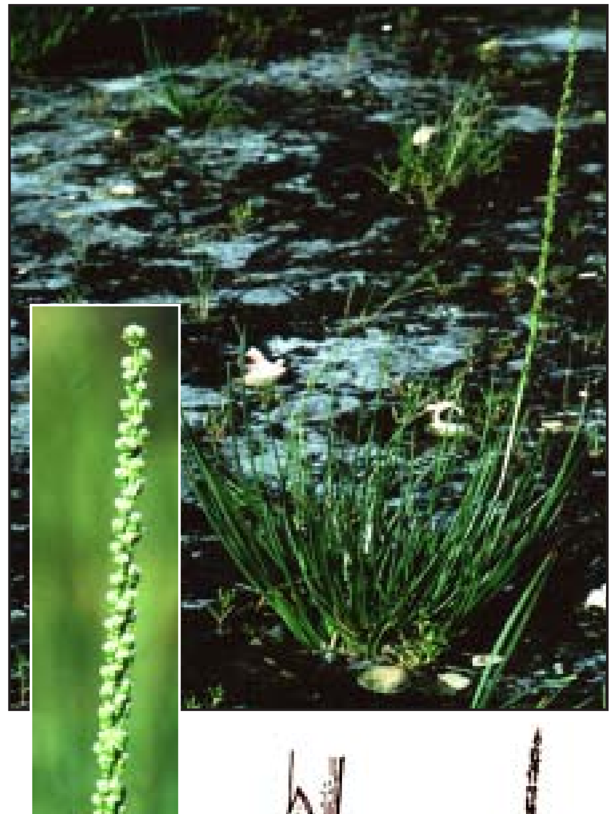

inflorescence


habit

S. virginica

Triglochin maritimum
SCIENTIFIC NAME

Seaside Arrowgrass
COMMON NAME



Fleshy, succulent leaves, 10 to 80 cm in length, occur as tufts emerging from short, stout rhizomes. The blades are somewhat flattened and are 1.5 to 2.5 cm in width. Each leaf is characterized by a basal sheath that encircles up to as much as one-third of the lower portion of an immediately preceding older leaf.

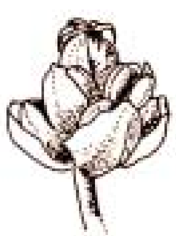
The flowering stem, 30 to 120 cm in length, emerges from the centre of the tuft. Tiny green flowers, with distinctive feathery red to purple stamens, occur on individual stalks along the upper third of the stem. The dry fruits are elliptic-ovate (egg-shaped), approximately 5 mm in length, and are composed of six one-seeded compartments that split lengthwise along the central axis of the fruit.

Seaside arrowgrass often forms dense stands in low elevation tidal salt and brackish marshes that are inundated twice daily. Unlike stands dominated by sedges and bulrushes, coverage within these stands is often incomplete, with exposed substrates occurring between the tufts of individual plants. It occurs sporadically within high elevation tidal marshes that are typically inundated only once per day. It occurs throughout coastal British Columbia.

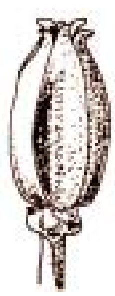
Seaside arrowgrass occurs sporadically within stands of saltgrass and pickleweed. It may be found with Lyngby's sedge, American threesquare, softstem bulrush, hardstem bulrush and saltmarsh bulrush in brackish marshes.

basal sheath

habit



flower



fruit

basal tuft

Typha latifolia

SCIENTIFIC NAME

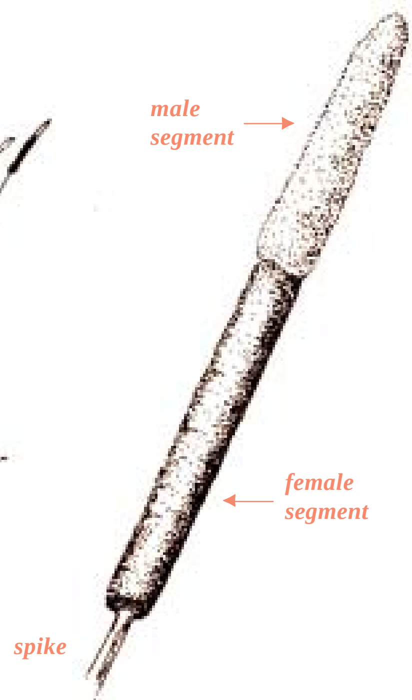
Broadleaved Cattail

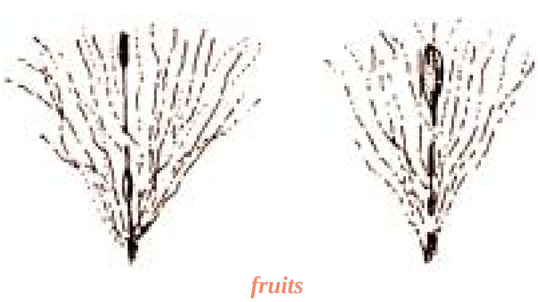
COMMON NAME

The cylindrical, pithy stems of broadleaved cattail grow to 3 m in height. The alternating leaves are sheathing, strap-like, convex, and 8 to 20 mm in width. The stems emerge from large, stout rhizomes.

The tiny flowers are crowded within terminal, cylindrical spike-like inflorescences that are divided into distinct male and female segments. These segments are typically continuous, with the male segment occurring above the female. When flowering, there is a stark contrast between male and female segments, with the male bright yellow (with pollen), and the female bright green. When in fruit, the female segment consists of a dark brown cylinder 15 to 20 cm in length and 12 to 30 mm in width. The fruits consist of 1 mm long nutlets, ellipsoid in shape, with numerous hairs emerging from the base.

Broadleaved cattail is a very common species that occurs throughout British Columbia where saturated soil conditions persist. It often occurs as expansive monospecific stands. It is intolerant of salt water, and as a result, is restricted to very low salinity brackish and fresh wetlands. Within tidal fresh marshes it occurs at high elevations. In relatively well draining marshes, common community associates include reed canary grass, Lyngby's sedge and beaked sedge. In relatively poor draining marshes, common community associates include softstem bulrush, hardstem bulrush, small-fruited bulrush and jointed rush. Along the margins of lakes and within shallow fresh ponds, common community associates include softstem bulrush and hardstem bulrush.





Acer circinatum
SCIENTIFIC NAME

Vine Maple
COMMON NAME

Vine maple occurs as a shrub or small tree to 10 m in height, with a trunk diameter to 15 cm. Its habit varies from an upright single trunk with several branches to a sprawling assemblage of crooked, prostrate trunks. The bark is light green when young, becoming increasingly brown and marked with age.

The leaves are opposite, 3 to 12 cm across with 7 to 9 radiating lobes. The leaves are hairy upon emergence in spring, becoming hairless later during the growing season. The margins are single or double toothed. In autumn, leaves within shaded environments typically turn yellow, while leaves within exposed environments typically turn bright red.

The flowers range from 6 to 12 mm across, and are characterized by 5 red to purple sepals and 5 white petals. The flowers are borne in loose drooping clusters at the end of shoots. The flowers transform into winged fruits progressively from the top of the cluster to the bottom. Winged fruits are borne in pairs, each 2 to 4 cm in length. The fruits are oriented approximately 180° to each other. The fruits are initially green, turning bright red in late summer.

Vine maple occurs within a variety of woodland communities. It occurs within the understory of open canopy mixed woodlands, along the margins of dense canopy woodlands, and along the margins of streams and rivers within high elevation floodplain environments. It inhabits moist to wet sites; it is intolerant of flooding.

Common community associates include snowberry, Indian plum, thimbleberry and salmonberry.

leaf and fruits

flower

Acer macrophyllum
SCIENTIFIC NAME

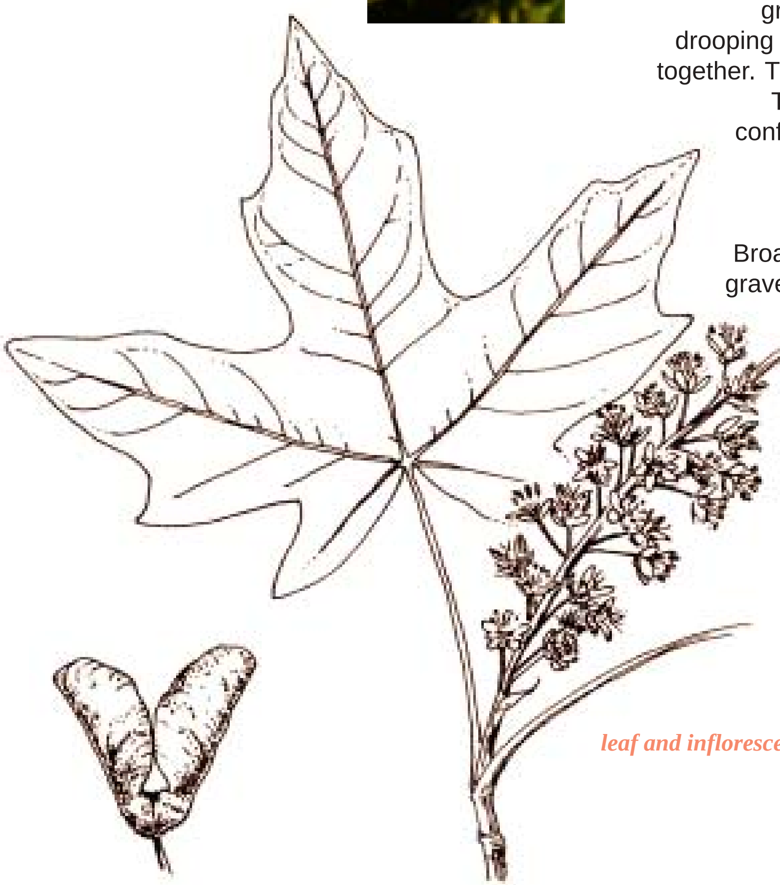
Broadleaf Maple
COMMON NAME

Broadleaf maple is a medium sized tree, growing up to 35 m in height and 100 cm in diameter. Its habit varies from a branch-free trunk with a narrow crown (within a dense stand of trees), to several large spreading and ascending limbs with a broad, rounded crown (within open woodlands). In young individuals, the bark is grayish-brown and smooth, while in older individuals, the bark displays narrow, scaly ridges.

The leaves are opposite with 5 deeply notched lobes. Leaves are typically 15 to 30 cm in width; they may be up to 60 cm across. In older trees, the leaves are dark green above and lighter below. In younger trees, the leaves appear somewhat lighter, almost chlorotic. The leaves turn yellow in autumn.

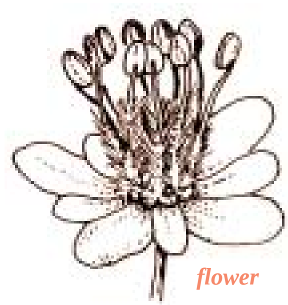
The flowers are approximately 10 mm across, greenish yellow, and occur within hanging drooping clusters. Male and female flowers occur together. They typically emerge prior to the leaves. The winged fruits emerge in pairs, in a 'v' configuration, and are each approximately 3 to 6 cm long. The swollen seedcase is covered with small, needle-like hairs.

Broadleaf maple typically occurs on coarse, gravelly, moist soils in pure or mixed stands. Common understory and edge species include vine maple, Saskatoon, beaked hazelnut, thimbleberry, salmonberry, Indian plum, red elderberry and snowberry.



leaf and inflorescence

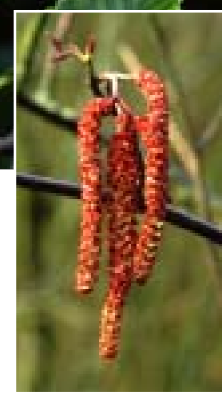
fruits



flower

Alnus rubra
SCIENTIFIC NAME

Red Alder
COMMON NAME



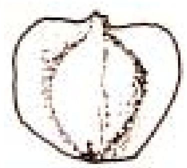
Red alder is a medium sized tree that grows up to 25 m in height and 80 cm in diameter. The bark is smooth, thin and light gray in colour. The bark of older trees is lightly furrowed. New shoots are angular and lobbing.

The leaves are oval to rhombic, 5 to 15 cm long, and tapered from the middle to both ends. Leaves are dull green above and range in colour below from grey-green (young leaves) to rusty brown (old leaves). The margin is double-toothed and rolled under. There is considerable leaf fall during the summer; the leaves remain green above until they fall.

The flowers are borne on catkins. The catkins flower before the leaves have enlarged, developing on the growth of the previous season. Flowering male catkins are 10 to 15 cm in length. Flowering female catkins are up to 5 mm in length.

Mature female catkins are woody, ovoid-ellipsoid structures, 1.5 to 2 cm in length and 1 cm in width. The nutlets are about 2 mm in length, narrow winged or encircled by a wing. The nutlets ripen in late autumn and are shed throughout late autumn and winter.

Red alder is restricted to the coast, where it is often the most common broadleaved tree. It is one of the first colonizers of cleared lands, often establishing near monospecific stands. It is often a dominant tree of tidal swamps that are inundated no more than once during each tide cycle.



nutlet

flowering female (short) and male (long) catkins

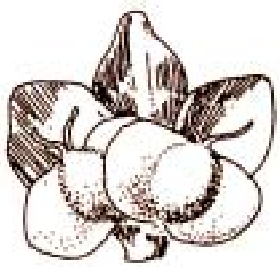
leaves and mature female catkins

Betula papyrifera

SCIENTIFIC NAME

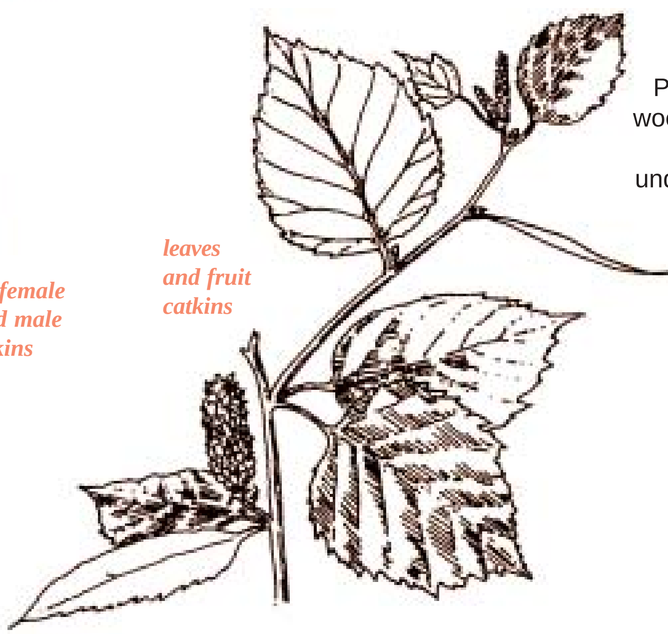
Paper Birch

COMMON NAME



nutlets

flowering female (short) and male (long) catkins



leaves and fruit catkins

Paper birch occurs as a short tree, to 20 m in height with tight reddish bark, or a tall tree, to 35 m in height with orange-white bark. In general, the bark is thin, dark red to almost black on young stems, becoming reddish-brown and then creamy white, often shredding in large sheets. Dark lenticels adorn the bark throughout.

The leaves are 5 to 10 cm long, oval to triangular with the tip pointed. The base of the leaf is broadly wedge shaped, rounded, straight, or cordate. The leaf margin is double-toothed (i.e. two teeth between veins). The leaves are dull green above and lighter below.

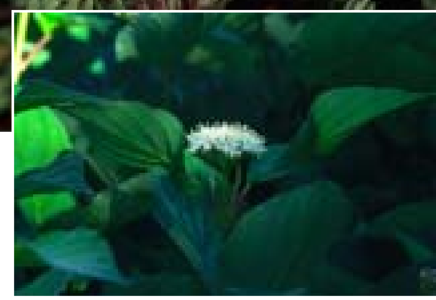
The male and female flowers occur on separate catkins. Immature male catkins occur in clusters of 1 to 3, are 1 to 3 cm long and 2 to 4 mm wide; pollen releasing catkins are approximately 9 cm long. Immature female catkins are 1 to 2 cm long, erect, with pink or red stigmas; mature female (seed) catkins are 3 to 5 cm long.

Nutlets are 1.5 to 2.5 mm long, and about half as wide; the wings are much wider than the nutlet. Attached scales are variable, approximately 2 to 3 mm in length, usually hairy, with 2 rounded lateral lobes diverging from a short pointed central lobe. Fruits and scales are shed from September onwards.

Paper birch typically grows in moist open woodlands. It often occurs within and along the margins of fens and bogs. Common understory and edge species include black twinberry, red osier dogwood, beaked hazelnut, Nootka rose, hardhack, thimbleberry and salmonberry. A common cohort within fens and bogs is shore pine.

Cornus stolonifera
SCIENTIFIC NAME

Red Osier Dogwood
COMMON NAME



Red osier dogwood occurs as a small to large shrub 1 to 6 m in height. It is freely branched, and often exhibits a prostrate habit. The branches are opposite. During the growing season, the bark of young stems is light to dark green, with older bark often displaying patches of grey callus. Upon the onset of fall, the bark, especially that of young stems, turns bright red.

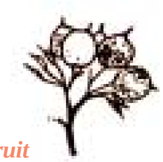
The leaves are opposite. The leaf buds are narrow and pointed, and in contrast to willows, are naked. The leaves are dark green above, and lighter and hairy below. The leaves are oval, 10 to 20 cm in length, smooth edged, with approximately 5-7 prominent veins that converge to a sharp point at the distal end of the leaf. The leaves turn a deep red in autumn.

The flowers are characterized by 4 small petals, 2 to 4 mm in length, white to green in colour. The flowers are organized in dense, flat topped terminal clusters.

The fruits consist of small, roundish drupes 6 to 9 mm in length. The drupes are white to faded blue in colour.

On the coast, red osier dogwood often flowers twice during the growing season. The first flowering occurs on the stems of the previous growing season during middle to late spring. The second flowering occurs on the stems of the current growing season during middle to late summer. The second flowers often occur on the plant together with the first berries.

Red osier dogwood grows along the margins and the floodplains of streams and rivers. It occurs within non-tidal and tidal swamps. Within open broadleaved forests, common community associates include black twinberry, salmonberry, Pacific ninebark, willows and cascara. Common community associates within fresh swamps include small-fruited bulrush, slough sedge, broadleaved cattail, hardhack, black twinberry and willows.



fruit

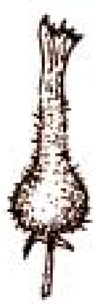
flower

leaves

Corylus cornuta
SCIENTIFIC NAME

Beaked Hazelnut
COMMON NAME

flowering female (red and short) and male (yellow and long) catkins



single fruit

twinned fruits and leaves

Beaked hazelenut is a large shrub, growing up to 6 m in height. Larger shrubs are characterized by densely clumped, spreading stems. Newly elongated shoots and leaves are covered in conspicuous soft, white hairs. The bark of young shoots and stems is greenish-brown to reddish-brown, with numerous, small lenticels. The lenticels on older bark are obscured by longitudinal fissures.

The alternate leaves are elliptic to ovate, being somewhat heart-shaped with a pointed tip. The margins of the leaves are doubly saw-toothed. The leaves are light green, paler below than above. Older plants display a conspicuous die-back of older leaves during mid-summer. The leaves turn a necrotic yellow in autumn.

The male flowers occur within slender catkins near the tips of shoots of the previous year. The female flowers are small and are enclosed within a bractlet. The purplish red styles of the female flowers barely extend beyond the bractlets. The catkins and bractlets appear during early autumn, overwintering prior to flowering.

The spherical, edible nuts are enclosed in tubular husks that are constricted beyond the apex of the nut into a beak. The husks are light green, sticky, and covered with stiff prickly hairs. The fruits occur in groups of 1 to 3.

Beaked hazelnut is characteristic of open broadleaved forests of southern British Columbia. It occurs within moist but well-drained sites at low to middle elevations. It occurs along streams and rivers in predominantly coarse, well-drained substrates.

Common community associates include snowberry, thimbleberry, red elderberry and Saskatoon.

Crataegus douglasii
SCIENTIFIC NAME

Black Hawthorn
COMMON NAME

Black hawthorn grows to 11 m in height. It displays both shrub and tree habits. The tree habit is often characterized by a crooked trunk(s). The shrub habit is multi-stemmed and scraggly in appearance. The bark is greyish brown with shredding scales. The branches are armed with thorns to 3 cm in length.

The alternate leaves are 2 to 8 cm in length, coarsely double-toothed with 5 to 9 lobes from the middle of the leaf to the distal end. The leaves are somewhat leathery with few hairs if present.

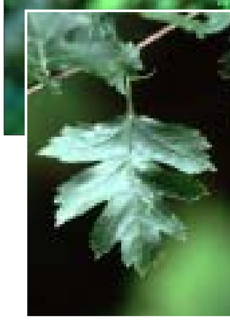
The white flowers are approximately 1 cm across and display 5 petals. They are borne in clusters terminally or at the leaf axil.

The fruits appear as little apples; they are ovoid, 8 to 10 cm across and dark reddish-purple in colour when ripe.

Along with other hawthorn species, black hawthorn is common along the fence rows of agricultural fields. It may be found within open broadleaved forests along the margins of streams and rivers. It occurs at the higher elevations of non-tidal and tidal fresh swamps. Common community associates include hardhack, Nootka rose, black twinberry, Pacific ninebark, red osier dogwood, willows and Pacific crabapple.

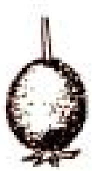
Another common species of hawthorn is the naturalized English hawthorn (*C. monogyna*). It can be distinguished from black hawthorn by its deeply lobed leaves and by thorns that bear leaves.

C. douglasii

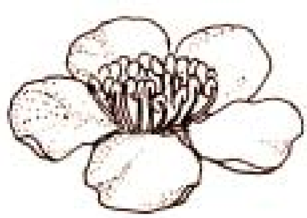


C. monogyna

leaves, fruits and thorns



fruit



flower

Lonicera involucrata

SCIENTIFIC NAME

Black Twinberry

COMMON NAME

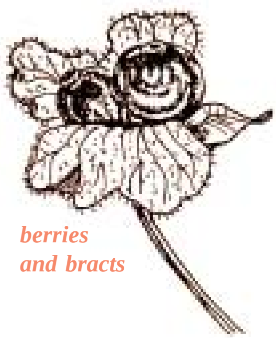
Black twinberry is a medium sized shrub that grows up to 3 m in height. It typically occurs as a scraggly assemblage of stems, rarely assuming the habit of an erect shrub. Young shoots (those that emerge during the current growing season) are light green and somewhat square to rectangular in cross-section.

The leaves are elliptical to broadly lance-shaped, 5 to 14 cm in length and 2 to 8 cm in width. They are medium to light green, and turn yellow to orange to red in autumn. They are glabrous above and pubescent below.

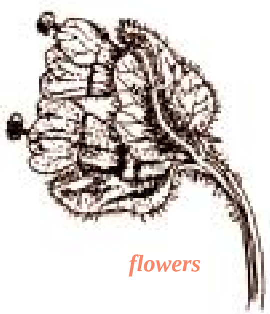
The yellow flowers are tubular with five lobes at the open end of the flower, each representing the distal portion of a fused petal. They occur as pairs, 1 to 2 cm in length, and are cupped at the base by green to purplish bracts.

The fruits are shiny black berries cupped by purplish to maroon bracts. The berries are approximately 1 cm across and produce 3 seeds.

Black twinberry is a common component of open forests along the margins and floodplains of streams and rivers. It is common within fens, and non-tidal and tidal fresh swamps. Common community associates include salmonberry, hardhack, red osier dogwood, willows, Pacific ninebark, Pacific crabapple, black hawthorn and cascara.



berries and bracts



flowers

berries and leaves

flowers and leaves

Osmaronia cerasiformis

SCIENTIFIC NAME

Indian Plum

COMMON NAME

Indian plum grows to 5 m in height. For its height it is not especially robust, being characterized by a myriad of loosely organized branches that typically bear leaves distally. It does not present a consistent habit. Young shoots (those that emerge during the current growing season) are light green, with older shoots purplish brown. Older plants often bear numerous dead branches.

The leaves are borne alternately along the stem and branches, with terminally borne leaves often presented in a whorl. The leaves are broadly lance shaped, 5 to 12 cm in length, with smooth margins. In late summer, older leaves commence to change colour from the characteristic light green to yellow with some orange. The appearance is distinctive; the plants display green leaves off the terminal shoots and yellow and orange leaves off subordinate shoots.

flowers and leaves

section of flower

The flowers of Indian plum are one of the first to emerge during early spring, emerging prior to the leaves. The flowers are greenish-white and occur within drooping clusters 5 to 10 cm in length. The clusters emerge from the nodes that bear the leaves. Male and female flowers are borne on separate plants. The calyx is partially fused, with the 5 petals emerging from a bell-shaped base. It is 6 to 7 mm in length, with petals 5 to 6 mm in length.

The fruits appear like small plums, displaying a bluish black colour when ripe. These small drupes are 8 to 10 mm in length. The seed is large relative to the overall size of the fruit.

Indian plum typically occurs within open broadleaved forests. It occurs sporadically along the margins of streams and rivers. Common community associates include snowberry, salmonberry, thimbleberry, red elderberry, red osier dogwood and vine maple.

external view of flower

fruits and leaves

Physocarpus capitatus

SCIENTIFIC NAME

Pacific Ninebark

COMMON NAME

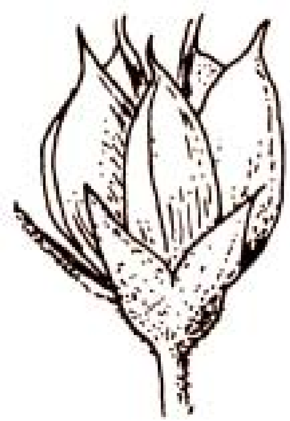
Pacific ninebark is a large shrub, attaining heights of up to 5 m. It typically occurs in clumps, with the major trunks and branches cascading or drooping. The bark is brown and shreds into thin strips.

The deciduous leaves are alternate, 3 to 6 cm in length, with 3 to 5 toothed lobes. They are shiny dark green above and lighter below with small hairs. The leaves turn a necrotic yellow in autumn.

The flowers are organized within rounded clusters. Each flower consists of 5 white petals and is approximately 8 mm across. The fruits consist of reddish brown dried follicles approximately 1 cm in length. The inflated follicles contain numerous small shiny seeds, each ranging in length from 2.3 to 2.8 mm.

Pacific ninebark occurs within moist to wet soils of open non-tidal and tidal fresh swamps, margins and floodplains of streams and rivers, and open broadleaved forests. Common community associates include red elderberry, salmonberry, thimbleberry, snowberry, hardhack, black twinberry, red osier dogwood, willows, black hawthorn, Pacific crabapple and cascara.

flowers and leaves



follicles

Picea sitchensis
SCIENTIFIC NAME

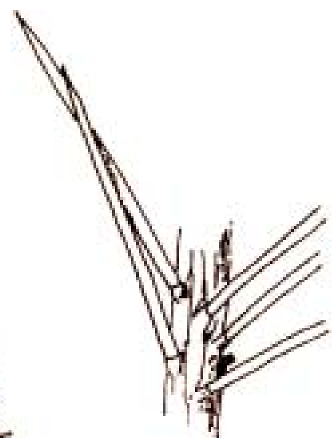
Sitka Spruce
COMMON NAME

Sitka spruce grows to 70 m in height and 2 m in diameter. The often buttressed trunk is massive, at times reaching widths of up to 5 m. The principal branches are horizontal with secondary branches drooping. The bark is thin, reddish-brown to grey-brown, breaking into small scales with age.

The needles vary from light green to blue-green in colour, with 2 white lines of stomata above and usually 2 relatively narrower lines below. The needles are stiff, very sharp, 4-sided, and somewhat flattened.

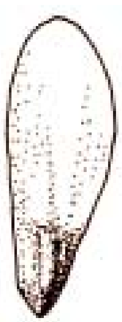
The male cones are red. The cylindrical female (seed) cones are 5 to 10 cm in length. When mature, the scales are yellow to light brown, thin, brittle, loose-fitting, elongated and broadest near the middle. The outer margin of each scale is wavy and irregularly toothed. The bracts are visible between open scales. The cones open during late autumn, and subsequently shed the reddish-brown, 2 to 3 mm long seeds that are adorned with 5 to 8 mm long wings.

Sitka spruce is typically maritime, occurring along the margins of inlets and riparian corridors to approximately 150 km inland and to 500 m in elevation. Notable exceptions are the Queen Charlotte Islands and southeast Alaska where Sitka spruce reaches the timberline. It occurs in pure or mixed stands, often on moist, well-drained sites such as alluvial floodplains. It also occurs on old logs or mounds within bogs.

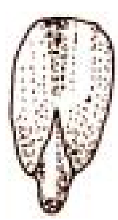


needle orientation

mature seed cones



winged seed



scale

needles

Pinus contorta var. *contorta*

SCIENTIFIC NAME

Shore Pine

COMMON NAME

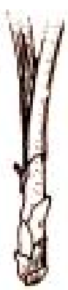
Shore pine is a small tree, growing up to 20 m in height, with multiple branches and a crooked trunk. The bark is thick, and becomes deeply furrowed with age into thick, coarse, dark reddish-brown plates.

Needles occur in pairs and are often curved and twisted. They range in length from 2 to 7 cm.

The yellowish-orange male (pollen) cones occur in clusters at the base of new shoots in spring. The small female (seed) cones are scarlet red in colour, and occur at the tip of the new shoots. Subsequent to pollination, a second phase of shoot elongation typically occurs, with the seed cone being positioned at the base of the second shoot. Upon maturity, the egg-shaped seed cones are 3 to 6 cm in length and often slightly curved. The scales are stiff and brown with a sharp prickle at the tip.

Shore pine inhabits a variety of habitats from dunes and bogs to rocky escarpments, knolls and exposed outer-coast shorelines.

Shore pine is one of two varieties of *Pinus contorta*. The other, lodgepole pine (*P. contorta* var. *latifolia*), is an inland tree that is relatively tall (to 30 m) and straight.



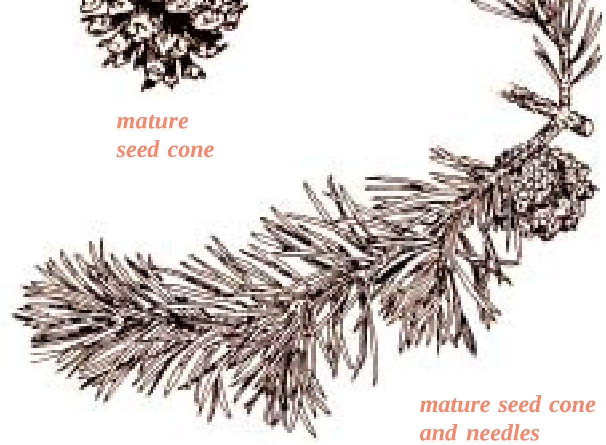
base of needle pair

cluster of pollen cones

mature seed cone

winged seed

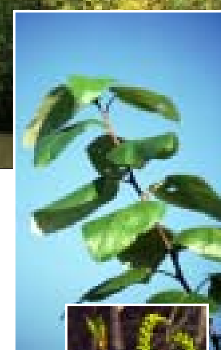
immature seed cone

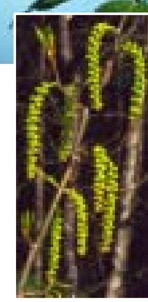


mature seed cone and needles

Populus trichocarpa
SCIENTIFIC NAME

Black Cottonwood
COMMON NAME





Black cottonwood is a large deciduous tree that grows to 60 m in height and 2 m in diameter. The bark of older trees is deeply furrowed and dark grey. The angular young shoots are adorned with sticky (resinous) buds, while the bark of young shoots is smooth, grayish-green or yellowish-grey.

The leaves are broadly ovate, 5 to 15 cm in length, sometimes wedge or heart-shaped with a sharply pointed tip. The margins of the leaves are finely toothed, the rounded teeth turning inward, so much so that the margins appear smooth. The leaves are dark green above and silvery green below, often marked with spots of dark resin. The leaves turn a necrotic to bright yellow in autumn. The petioles are round in cross section and 3 to 4 cm in length. They bear a pair of glands at the junction with the blade.

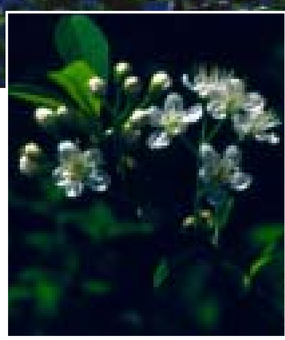
female flower

Flowers are borne on catkins. Male and female catkins, respectively, are 4 to 5 and 6 to 8 cm in length and occur on separate plants. Mature female (seed) catkins are 12 to 15 cm in length and bear many closely spaced capsules. The capsules are nearly globular, 3 to 4 mm in length, covered in short hairs, and split into 3 parts when mature. The seeds are 2 mm in length.

Black cottonwood often occurs as the dominant canopy species of floodplain forests of large rivers throughout coastal British Columbia. It is also often an important component of mixed riparian woodlands.

Common understory and edge species include vine maple, red osier dogwood, willows, red elderberry, snowberry, Pacific ninebark, black twinberry, thimbleberry, salmonberry and Indian plum.

leaves and female catkins



Prunus emarginata

SCIENTIFIC NAME

Bitter Cherry

COMMON NAME

The habit of bitter cherry varies from that of a scraggly shrub to that of a tree, 2 to 20 m in height, respectively. The trunk is slender relative to the crown. Young bark is dark brown with prominent orange lenticels; the lenticels of older bark are less prominent, becoming calloused and dark brown in colour.

The alternate leaves are dull yellowish-green, hairless to downy below. They are oblong to oval in shape, with a finely toothed margin and rounded at the tip; this is in contrast to choke cherry (*P. virginiana*) and many naturalized domestic cherries that are pointed at the tip. The 3 to 8 cm long leaves ascend or spread stiffly from the twig.

The flowers display 5 petals that are white to pinkish in colour. The flowers are 10 to 15 mm across and occur in flat topped clusters of 5 to 12 flowers.

The fruits are 1 seeded drupes that are red to almost black in colour. They are 6 to 15 mm across.

Bitter cherry is intolerant of shade. It occurs within open broadleaved woodlands along the margins of streams and rivers. It is often a pioneer species of recently cleared areas. As a tree, it is typically a minor canopy species. As a shrub, common community associates include salmonberry, thimbleberry, red osier dogwood, hazelnut, red elderberry, willows and vine maple.

flowers and leaves

fruit

Pseudotsuga menziesii
SCIENTIFIC NAME

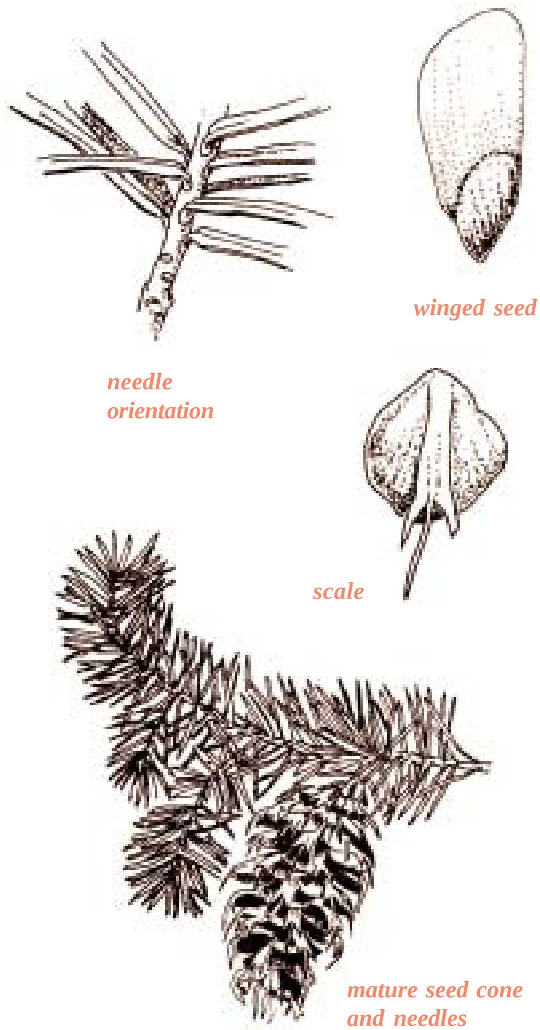
Douglas fir
COMMON NAME

Douglas fir is a large coniferous tree that grows to 70 m in height and 2 m in diameter. Young trees are characterized by pyramidal conical crowns with a stiffly erect leader. Older trees are characterized by long, branch-free cylindrical trunks and short, columnar, flat-topped crowns. The principal branches occur within irregular whorls, the upper of which often turning upright to look like additional leaders. The larger, lower branches typically droop. The mature bark is very thick, deeply furrowed, rough and dark brown.

The needles are flat, 2 to 3 cm in length with pointed tips. There is one groove above with 2 lines of white dots (stomata) below. The yellowish-green needles are spirally arranged along the twig, spreading out from the sides in 2 ranks or spreading out from 3 sides and moderately parted on the upper side.

The male cones are small, yellow to reddish-brown, catkin-like, 10 to 20 mm long and borne on short stalks. The male cones are borne from the upper-middle to lower portions of the crown. The female cones, at time of pollination, are oblong and approximately 30 mm in length, green to purple to red, erect on short stalks, with distinctive 3-pronged bracts extending beyond the scales and partially obscuring them. The mature seed cones are ovoid, 6 to 9 cm in length, yellowish-brown to purplish-brown on short stalks. The scales are numerous, broad, rounded and leathery. The bracts are prominent, 3-pronged and longer than the scales. The seeds are somewhat triangular, 5 to 7 mm in length, shiny reddish brown, and are adorned with a wing 15 to 18 mm in length.

Douglas fir occurs on a wide variety of soils, but does best on deep, well-drained sandy loams with ample moisture. It is commonly a pioneer species that regenerates after forest fires, logging and other disturbances. It is less shade tolerant than western hemlock, Sitka spruce and western redcedar. On the coast, Douglas fir is typically succeeded by western hemlock, except on dry, rocky sites and areas influenced by fire.



Pyrus fusca
SCIENTIFIC NAME

Pacific Crabapple
COMMON NAME

Pacific crabapple is a shrub or small tree, ranging from 2 to 12 m in height. It is armed with sharp spur-shoots. Older bark is deeply fissured.

Typically, the alternate leaves are lance to egg-shaped and up to 10 cm in length. The margins are adorned with sharp, forward pointing teeth. The leaves of new shoots are often characterized by one or more prominent lobes. The leaves turn yellow to dark red in autumn.

The flowers are white to pink, have 5 petals, are approximately 2 cm across, and occur in clusters of 5 to 12. The fruits are yellow to reddish-orange when ripe, longer than wide and 12 to 20 mm in length.

Pacific crabapple occurs within tidal and non-tidal fresh swamps, fens, bogs, along the margins of coastal streams and rivers, and within moist open woods. Within swamps, common community associates include cascara, willows, black hawthorn, black twinberry, red osier dogwood, Pacific ninebark, hardhack and Nootka rose. Along the margins of streams and rivers and moist open woods, common community associates include salmonberry, red osier dogwood, Pacific ninebark and cascara.

fruits and leaves

flowers and leaves

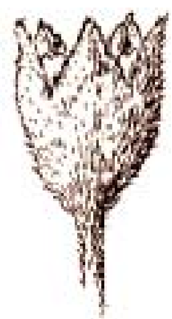
Rhamnus purshiana
SCIENTIFIC NAME

Cascara
COMMON NAME

Cascara is a large shrub to small tree that grows to 10 m in height. The bark is thin; it is smooth, dark grayish-brown in young individuals becoming increasingly scaly with age. The dark green leaves appear waxy, are 4 to 16 cm in length, and are slightly hairy underneath. The margins of the somewhat ovate to oblong leaves are finely toothed. The apical leaves in young individuals often persist through winter.

The greenish-yellow flowers occur in clusters at the apical cluster of leaves on branches. They are small, 3 to 4 mm in diameter, and bear 5 sepals, petals and stamens. They typically bloom from late May through June.

The bluish-black to purplish-black berries are approximately 5 to 8 mm in width. Ripe berries when handled readily stain, leaving a blotch reminiscent of that left by an exploded ball-point pen. The pits are large, 4 to 7 mm in width.



flowers, section and exterior view

Cascara is a common inhabitant of fresh swamps, occurring within riverine floodplains and along the margins of lakes. It often occurs within mixed upland woodlands, often as a minor component of the canopy layer within predominantly deciduous mixed woodlands, or as a perimeter or subcanopy species within canopy breaks of predominantly coniferous mixed woodlands.

As a shrub, common community associates include black twinberry, willows, Pacific ninebark, red osier dogwood and Pacific crabapple.

leaves and fruits

Rosa nutkana

SCIENTIFIC NAME

Nootka Rose

COMMON NAME

Nootka rose is a medium sized shrub that grows to 3 m in height. Large thorns adorn new shoots, while old shoots are typically unarmed.

The alternate leaves are divided into 5 to 7 leaflets. The leaflets are 1 to 7 cm in length, elliptic in shape and toothed along the margin.

The flowers display 5 petals that are light pink to deep rose in colour. The individual flowers are 4 to 8 cm across and are typically borne terminally on branches.

The fruits (hips) are purplish-red, round and 1 to 2 cm across. They contain numerous bony hairy achenes, 4 to 6 mm in length.

Nootka rose occurs most frequently along the margins and the floodplains of streams and rivers as a component of open shrub woodlands. It occurs sporadically at the highest elevations of tidal fresh and brackish swamps. Common community associates include salmonberry, thimbleberry, snowberry, hardhack, red elderberry, willows, Pacific crabapple and black hawthorn. It and red elderberry are often the most prevalent shrubs, within old field landscapes.

hips

hip and leaves

flower and leaves

Rubus parviflorus

SCIENTIFIC NAME

Thimbleberry

COMMON NAME

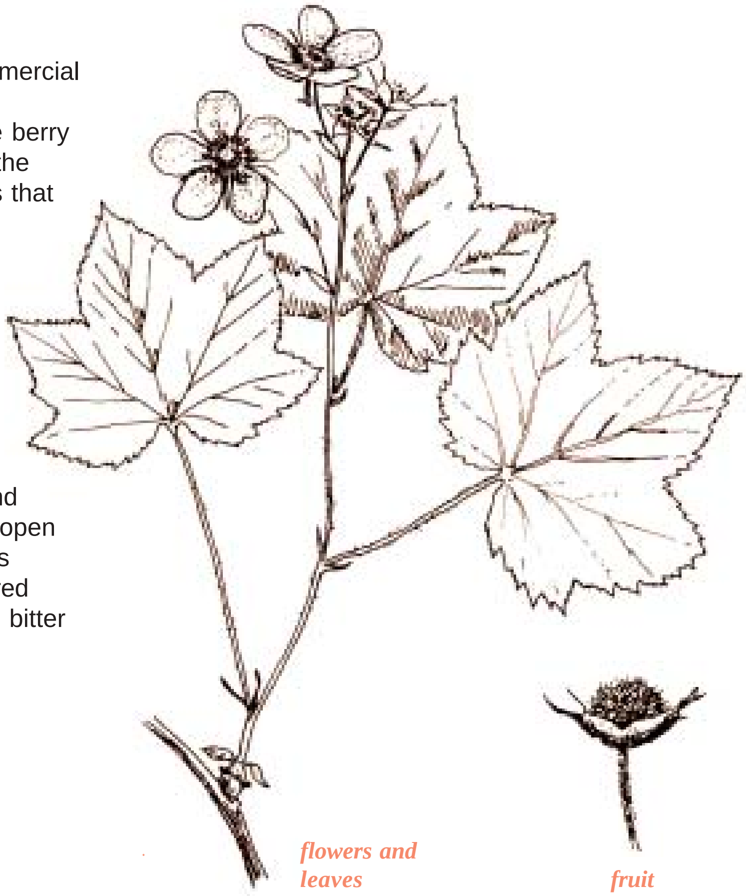
Thimbleberry is a medium sized rhizomatous shrub that grows to 3 m in height. It often forms dense thickets. The bark of young green shoots (those that emerge during the current growing season) is hairy and somewhat glandular. The bark of older stems and branches is brown and shredding.

The leaves alternate along the stem and branches. In contrast to salmonberry leaves, thimbleberry leaves are not dissected, being maple-leaf shaped with 3 to 7 distinct lobes. The leaves are large, up to 25 cm across. Both sides of the leaves are adorned with small hairs, rendering the leaves somewhat fuzzy.

The flowers are white with 5 petals. The petals are somewhat crinkled in habit, much like crepe paper. The flowers occur in groups of 3 to 11 on the end of relatively long branches.

The fruit is an aggregate of small berries, displaying a habit similar to that of the commercial raspberry. Relics of the sepals (5) are conspicuous, emerging from the base of the berry to provide a star-like backdrop. When ripe, the berries are red and adorned with small hairs that make the berries fuzzy. In contrast to salmonberries, the general shape of the aggregation is semi-spherical, presenting the appearance of a small dome.

Although thimbleberry and salmonberry often occur together, thimbleberry, in general, occurs within environments that are drier than those inhabited by salmonberry. It occurs along the margins and floodplains of streams and rivers and within open woodlands. Common community associates include salmonberry, Indian plum, snowberry, red elderberry, red osier dogwood, hazelnut and bitter cherry.

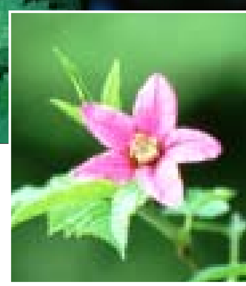


flowers and leaves

fruit

Rubus spectabilis
SCIENTIFIC NAME

Salmonberry
COMMON NAME



Salmonberry grows to approximately 4 m in height and is characterized by light woody stems that break easily. The green young stems (those that emerge during the current growing season) are lightly armed with small thorns; these thorns fall off older stems as the golden bark shreds. Salmonberry is characterized by branching rhizomes that facilitate the establishment of dense thickets. Both the main stem and branches have a crooked habit, zigzagging from node to node.

The alternate leaves are typically divided into three somewhat triangular leaflets. The leaves are dark green and sharply toothed.

The flowers display 5 pink to purplish petals. The flowers are 4 cm across and are borne on short leafy branches.

The fruit is an aggregate of small berries, displaying a habit similar to that of the commercial raspberry. The aggregation is somewhat elongated. The colour of the berries range from orange-yellow to dark red.

Salmonberry occurs as dense thickets along the margins and floodplains of streams and rivers, and along the margins of non-tidal and tidal fresh swamps. It is a common inhabitant of moist open forests and is common at seeps within drier environments. It is tolerant of widely fluctuating water tables. Common community associates within relatively well draining environments, in proximity to streams and rivers, include Indian plum, thimbleberry, red elderberry, red osier dogwood, Pacific ninebark, willows and vine maple. Within swamps, common community associates include hardhack, black twinberry, Pacific ninebark, red osier dogwood, willows, Pacific crabapple, black hawthorn and cascara.

flowers and leaves

Salix hookeriana
S. piperi
SCIENTIFIC NAMES

Hooker's Willow
Piper's Willow
COMMON NAMES

Hooker's willow grows to 6 m in height. The twigs are stout, dark brown and covered with gray woolly hairs for the first 2 to 3 years. The bark of older stems is light reddish brown, shallowly furrowed, with tight scales. Lenticels that adorn the bark of young stems are orange.

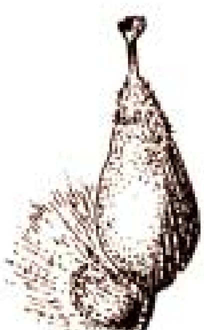
The alternate leaves are oval to egg-shaped. The leaves are 4 to 12 cm in length and 2 to 6 cm in width, typically without a toothed margin. The tip of the leaves is rounded. Young leaves are very hairy. The upper surface of the older leaves is nearly smooth. The stipules are small and are shed early in the growing season.

The flowers are borne on catkins, which are in turn borne on short shoots with bract-like leaves. Immature catkins are densely covered with silky hairs. The catkins are fully developed prior to the emergence of leaves. Female catkins achieve lengths of up to 12 cm, while male catkins achieve lengths of up to 4 cm.

The fruits consist of dry, dehiscent capsules that are fleshy upon initial development. They are cylindrical, 8 mm in length, beaked and smooth to somewhat hairy.

S. hookeriana

leaves



capsule

female catkins

S. hookeriana

male catkins

S. hookeriana

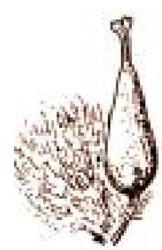
Piper's willow is very similar to Hooker's willow. The shoots and leaves are not as hairy as those of Hooker's willow. Upon elongation, the new shoots are finely haired; the hairs are quickly shed. Similarly, the leaves are finely haired upon emergence and soon become smooth. The leaves are typically at least 4 times as long as wide, with rounded to pointed teeth along the margin. The most conspicuous distinction between Piper's and Hooker's willow is the presence of well developed, leaf-like stipules on Piper's willow. Both willows readily hybridize.

These two willows grow in wet environments, from open shrub swamps to the margins and floodplains of streams and rivers within open broadleaved forests. Common community associates include red osier dogwood, hardhack, salmonberry, black twinberry, other willows, Pacific ninebark, Pacific crabapple, black hawthorn and cascara.

S. piperi

male catkins

leaves



capsule

female catkins

Salix lasiandra

SCIENTIFIC NAME

Pacific Willow

COMMON NAME

Pacific willow grows to 12 m in height. Within saturated soils, Pacific willow assumes a shrub habitat, typically with a crooked trunk and a ragged, round crown. Within drier soils, it assumes a tree habitat, with a relatively straight trunk and a more uniform, columnar crown. Pacific willow is distinguishable by its yellow shoots. The bark on young shrubs and trees is somewhat shiny and grayish brown in colour. The bark is dark gray and furrowed on older individuals.

The alternate leaves are lance-shaped with a long, tapered tip. The leaves are 5 to 15 cm in length, with the margins finely toothed. Underneath, the midvein is orange-yellow in colour, with the remainder of the leaf whitish and somewhat hairy. Above, the leaf is dark green. The kidney-shaped stipules are borne at the base of a 3 to 15 mm long leaf stalk. Glands are borne on the stalk at the base of the leaf.

The flowers are borne on catkins. The bracts are pale yellow, hairy and are shed after flowering. The catkins emerge with the leaves on short leafy shoots. Female catkins achieve lengths of up to 12 cm, while male catkins grow to 7 cm in length.

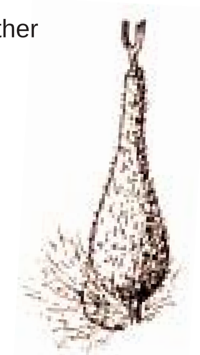
The fruits consist of dry, dehiscent capsules that are fleshy upon initial development. The capsules are somewhat conical with a constriction at the middle. They are 4 to 8 mm in length and hairless.

Pacific willow occurs along the margins and within the floodplains of streams and rivers. It occurs within non-tidal and tidal fresh swamps. Common community associates as a shrub include red osier dogwood, black twinberry, salmonberry, Pacific ninebark, other willows, Pacific crabapple, black hawthorn and cascara.

stipules

male catkins and leaves

male flower



capsule

female catkins and leaves

Salix scouleriana

SCIENTIFIC NAME

Scouler's Willow

COMMON NAME

Scouler's willow grows to 12 m in height. Its habit ranges from a tall shrub to a tree. The bark of older trunks and stems is dark brown with ridges. Younger stems and twigs are yellowish to greenish brown with a covering of dense hairs.

The alternate leaves are somewhat egg-shaped, 5 to 12 cm long. The tips are pointed to blunt, with the base tapering. The margin is smooth or sparsely toothed near the base. New leaves are adorned with downy hairs, more densely so below than above. At maturity, the leaves are dark green and smooth or sparsely haired above, and smooth or finely haired below. The stipules occur at the base of the 5 to 10 mm long leaf stalk. The stipules are pointed and are shed early in the growing season.

The flowers are borne on catkins. The stalkless catkins emerge prior to the leaves. The bracts are brown to black in colour, 4 to 5 mm in length and hairy. Female catkins are 2 to 6 cm in length, while male catkins are 2 to 4 cm in length.

The fruits consist of dry, dehiscent capsules that are fleshy upon initial development. The capsules are covered with silky hairs and are 5 to 8 mm in length. They are narrow and conical with a beak approximately 2 mm in length.

Scouler's willow occurs along the margins and within the floodplains of streams and rivers. It may be found within non-tidal and tidal swamps. Common community associates as a shrub include red osier dogwood, black twinberry, salmonberry, Pacific ninebark, other willows, Pacific crabapple, black hawthorn, cascara and red alder.

leaves

male catkins

female catkins

Salix sitchensis
SCIENTIFIC NAME

Sitka Willow
COMMON NAME

The habit of Sitka willow ranges from that of a shrub to that of a small tree 8 m in height. The bark is dark brown to grey, with the bark of older trunks and stems slightly furrowed. New shoots are dark reddish-brown and covered with dense, fine hairs.

The leaves of Sitka willow are 4 to 9 cm in length. They are somewhat egg-shaped, with a blunt-pointed tip and tapering to a narrow base. The margins are smooth or adorned with small wavy teeth. Above, the leaves are dark green with few hairs, while below they are covered with short white hairs that render the surface whitish. The stipules are borne at the base of the 5 to 15 mm long leaf stalks. The stipules are small, approximately 1 mm in length, and half-oval in shape. The stipules may be shed early or retained throughout the growing season.

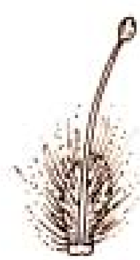
The flowers are borne on catkins. The catkins are in turn borne on short leafy shoots. They appear both before and during leaf emergence. Female catkins achieve lengths of up to 8 cm, while male catkins achieve lengths to 5 cm. The bracts are brown, hairy and 2 to 3 mm in length.

The fruits consist of dry, dehiscent capsules that are fleshy upon initial development. The capsules are covered with silky hairs and are 3 to 5.5 mm in length. They are somewhat conical with a short beak.

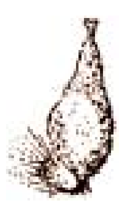
Sitka willow occurs along the margins and within the floodplains of streams and rivers. It may be found within non-tidal and tidal swamps. Common community associates as a shrub include red osier dogwood, black twinberry, salmonberry, Pacific ninebark, other willows, Pacific crabapple, black hawthorn and cascara.

male catkins and leaves

fruiting female catkins and leaves



male flower



capsule

Sambucus racemosa

SCIENTIFIC NAME

Red Elderberry

COMMON NAME

Red elderberry grows to 6 m in height. Although its habit ranges from a small shrub to a small tree, it typically occurs as a large multi-stemmed shrub. The bark of young stems is greenish to reddish brown in colour and is adorned with many warty lenticels. The bark of older stems is vertically fissured, forming scaly ridges. The stems are characterized by a central core of pith.

The leaves are opposite and large, consisting of 5 to 7 leaflets on a grooved central stalk. The leaflets are 5 to 16 cm in length, have a sharply toothed margin, and are borne on 6 to 12 long stalks. The leaflets are hairy along the veins. They are typically lance-shaped, about half as wide as long. The colour of the leaves turn a necrotic yellow in autumn.

The flowers bear 5 petals, are 3 to 6 mm across, and are yellowish to white in colour. They are contained within individual round clusters which are in turn organized within a larger round or pyramidal cluster. The fruits are berry-like drupes. The fruits are more or less round, 5 to 6 mm across. Each drupe bears 3 to 5 smooth seeds. The fruits are typically bright red; yellow, purple-black, brown and white colour phases have also been documented.

inflorescence and leaf

On the coast, red elderberry often flowers twice during the growing season. The first flowering occurs on stems of the previous season during leaf emergence in early spring while the second flowering occurs on stems of the current season during middle to late summer. The second flowers often occur on the plant together with the first berries.

Red elderberry is often abundant within open broadleaved forests characterized by moist to wet soil conditions. It is an indicator of rapid decomposition of forest floor materials remaining on cutover or fire disturbed sites. Common community associates within open woodlands include thimbleberry, salmonberry, snowberry, Pacific ninebark, beaked hazelnut, red alder and broadleaf maple. Red elderberry is an early colonizer of moist old fields; a common cohort in these fields is Nootka rose.

Sorbus sitchensis
S. scopulina
S. aucuparia
SCIENTIFIC NAMES

Sitka Mountain Ash
Western Mountain Ash
European Mountain Ash
COMMON NAMES

Sitka mountain ash is a native mountain ash common to coastal British Columbia. Western mountain ash, also a native, is more common within the interior of British Columbia. European mountain ash, a non-native as the name implies, occurs predominantly within urban and rural areas. All three species readily hybridize.

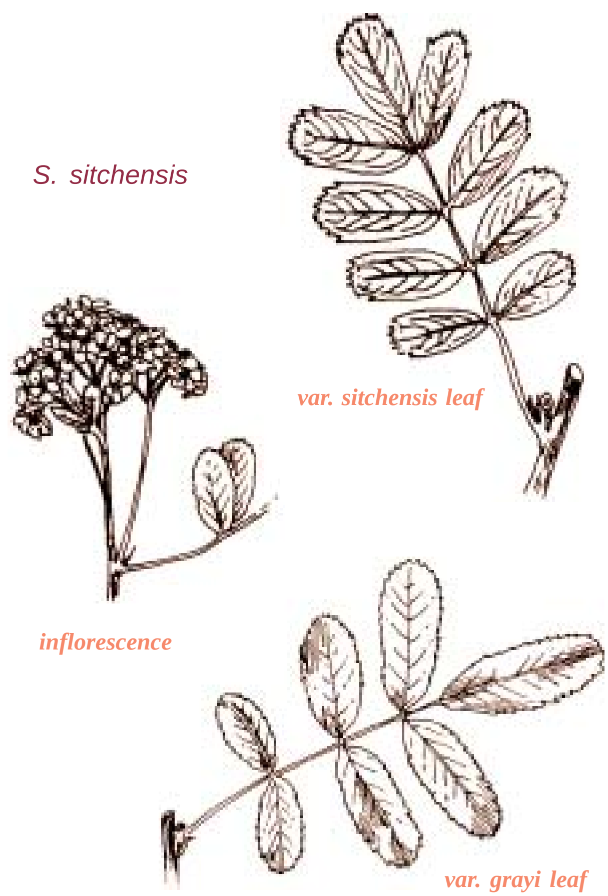
All three species of mountain ash display a shrub to small tree habit. Sitka ash, western ash and European ash grow to 6 m, 4 m and 12 m in height, respectively. The bark of all three species is thin, smooth and light gray with horizontally elongated lenticels. The bark becomes scaly with age. The new shoots of Sitka ash have rusty hairs and are not sticky. Western ash displays new shoots that have white hairs and are sticky. The new shoots of European ash have white hairs that are not sticky.

The leaves are alternate and are divided into leaflets in all three species. Sitka ash leaves are divided into 7 to 11 leaflets that are elliptic, 2 to 6 cm in length, rounded to nearly flat at the tip, with teeth along the margin of the leaflets from the approximate middle of the leaflet to the tip. Western ash leaves are divided into 9 to 13 leaflets that are narrowly oblong to oblong-lanceolate, 3 to 7 cm in length, tapered to a sharp point at the tip, with teeth along the entire margin of the leaflet. European ash leaves are divided into 9 to 17 leaflets that are oblong to oblong-lanceolate, with coarse teeth along the margin except in proximity to the base of the leaflet.

Mountain ash flowers have 5 white petals and are borne in flat-topped or rounded clusters at the tip of a shoot. The flowers appear after the leaves are fully grown. Sitka ash flowers are 6 to 8 mm across and are borne within rounded clusters; 15 to 80 flowers occur within each cluster. Western ash flowers are 10 to 12 mm across and are borne

S. aucuparia

S. sitchensis



S. aucuparia

within nearly flat-topped clusters; 70 to greater than 200 flowers occur within each cluster. European ash flowers are approximately 8 mm across and are borne within flat-topped clusters; at least 75 flowers occur within each cluster.

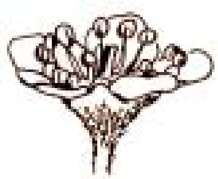
The fruits of mountain ash are berries. Sitka ash berries are ellipsoid to almost round. They are approximately 10 mm in length and red with a whitish, removable cast that renders the berries bluish. Western ash berries are nearly round, approximately 10 mm long, and a glossy yellowish-orange to scarlet red in colour. European ash berries are round, orange to bright red, and 10 to 12 mm in length.

European ash has been observed to drop the majority of its leaves during late summer when the berries ripen; new shoots subsequently emerge, with new leaves and flowers. This new growth typically does not result in new fruits.

Sitka and western mountain ash are common but scattered within open broadleaved and coniferous forests. They are especially persistent within clearings. European mountain ash is common within urban and rural environments, where the seeds of individuals planted as ornamentals are scattered by birds throughout the landscape.

S. aucuparia

leaf



typical flower

inflorescence

var. cascadensis leaf and inflorescence

var. scopulina leaf and berries

S. scopulina

Spiraea douglasii
SCIENTIFIC NAME

Hardhack
COMMON NAME

Hardhack is a medium sized shrub, growing to 2.5 m in height. It is erect and multi-branched. Young shoots (those that emerge during the current growing season) display reddish-brown bark and dense hairs. Older stems and branches have dark brown bark that is relatively smooth and longitudinally shredding.

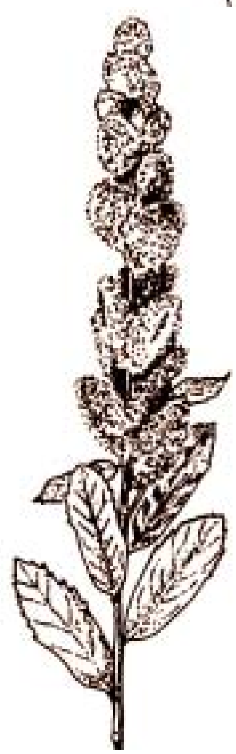
The leaves are dark green above and light green to grayish and pubescent below. They are oblong to oval and 3 to 8 cm in length. The leaves possess distinctive teeth from the middle to the end of the leaf.

The pink to deep rose flowers occur within a terminal inflorescence 10 to 20 cm in height and less than half as wide. Individual flowers are very small, less than 5 mm across.

The inflorescence turns brown when the fruits ripen. The fruits consist of small pod-like follicles, with the small seeds released when the follicle splits.

Hardhack is extremely shade intolerant. Within wet meadows and shallow fresh swamps, it forms large thickets that often become the dominant cover of the wetland. Within fens, it occurs along the margins of drainage channels and seeps, the fresh water apparently ameliorating the acidity of the fen, thereby allowing hardhack to persist. It also occurs as dense thickets at the high elevations of tidal fresh and brackish swamps and along the shorelines of shallow lakes. A common community associate within fens is sweet gale (*Myrica gale*). Within wet meadows common community associates include beaked sedge, soft rush, small-fruited bulrush and reed canary grass. Within swamps, common community associates include red osier dogwood, willows, black twinberry, Nootka rose, Pacific crabapple and black hawthorn.

flower



inflorescence

Symphoricarpos albus
SCIENTIFIC NAME

Snowberry
COMMON NAME

Snowberry is a small, erect shrub that grows up to 2 m in height. A centre core of pith characterizes young stems while older stems are hollow. The thin brown bark of older stems peels off as flakes. The shrub is rhizomatous and readily roots from the nodes of its stems and rhizomes.

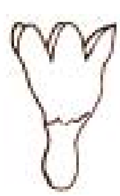
Snowberry is heterophyllous; a single plant may have leaves of many different shapes and sizes. Typically, the leaves of young shoots (those that emerge during the current growing season) are deeply lobed, displaying a pattern that is rarely reproduced from one leaf to another. In contrast, the leaves of older shoots are regularly elliptic to oval, 2 to 5 cm in length.

The bell-shaped flowers (snowberry is within the honeysuckle family) are pink to white in colour. Five lobes extend from the flower tube. The entire flower is 5 to 7 mm in length. The flowers occur within small clusters at the end of old shoots.

The fruits are berry-like drupes. They are irregular in shape and 6 to 15 mm in width. Two (2) relatively large seeds are produced by each drupe.

Snowberry is a common inhabitant of open forests along the margins and floodplains of streams and rivers. Common community associates include red elderberry, Indian plum, beaked hazelnut, thimbleberry, salmonberry and vine maple.

leaves and flowers



external view of flower

section of flower displaying stamens and pistils

Thuja plicata
SCIENTIFIC NAME

Western Redcedar
COMMON NAME

Western redcedar is a large coniferous tree that grows to 60 m in height and 2.5 m in diameter. The crown, symmetrical and narrowly conical in young trees, becomes increasingly irregular with age. The principal branches are spreading, slightly drooping, with upturned ends. Branchlets are strongly flattened and fern-like, and are often pendulous. The bark of young growth is thin, reddish-brown and shiny; older growth is characterized by shreds and narrow ridges. The trunk of mature trees is strongly buttressed at the base.

The scale-like leaves are 1 to 2 mm in length with small inconspicuous resin glands on the outer surface. The leaves, shiny and yellowish-green in colour, occur as opposite pairs, with those of one pair folded and the other not, overlapping in a shingled arrangement resembling a tight, flattened braid. The leaves are ultimately deciduous, having a life of 3 to 4 years; commencing in late summer, branches are conspicuous in possessing green (live) and red-brown (dead) branchlets distally and proximally, respectively.

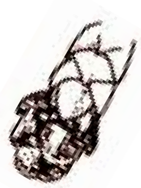
The male cones are more or less spherical and to 2 mm in length. The female cones are ovoid, brown and 12 to 18 mm in length at maturity. Juvenile cones are bluish green. The cones typically have 8 to 10 scales with a small, weak, sharp pointed tip. The scales contain seeds 6 to 7 mm in length. The seeds are adorned with lateral wings that are almost as wide and somewhat longer than the seeds.

Western redcedar grows best on alluvial sites. It may also be found on rich dry soils and in sphagnum bogs. It rarely occurs as pure stands.

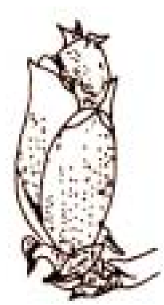
orientation of scales

winged seed

branch



male cone



female cone

Tsuga heterophylla

SCIENTIFIC NAME

Western Hemlock

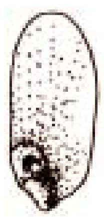
COMMON NAME

Western hemlock is a large coniferous tree that grows to 60 m in height and 1.2 m in diameter. The leader is conspicuously drooping, with the principal branches mostly downsweeping. The lower portion of the trunk in mature trees is branchless. The bark is reddish brown and smooth in young trees; it is rough, scaly, thick and furrowed in older trees.

The needles are flat, blunt-tipped, widely and irregularly spaced, and of unequal length (5 to 20 mm). The needles are shiny dark green and grooved above, and whitened below with ill-defined lines of white dots (stomata) on either side of the midvein. The needles are clearly arranged in 2 ranks, with a few shorter ones on the upper side pressed against the twig.

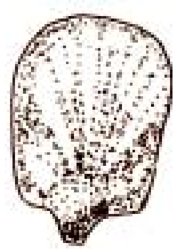
The seed cones are ovoid, 20 to 25 mm in length, blunt tipped, short stalked, purplish-green when young and golden brown when mature. The scales are rectangular, tips rounded, and the margin smooth or faintly toothed. The cones open in autumn and the seeds are shed gradually. The cones may stay on the tree for up to 2 years.

Western hemlock is extremely shade tolerant, regenerating well under a closed canopy. It grows best on organic soils, and is often found growing on rotten logs or partially decomposed forest litter. It also grows in full sunlight, and requires high soil moisture and a humid environment for good regeneration and growth.



orientation of scales

post pollen male cones and seed cones



scale

needle orientation

branch and needles