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# Status Report on Coastal Sand Ecosystems in British Columbia

Nick Page and Patrick Lilley
RAINCOAST APPLIED ECOLOGY

Ian J. Walker
NELSON-WALKER GEOGRAPHIC CONSULTANTS

Ross G. Vennesland
PARKS CANADA

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**Cover illustrations:** From left to right: photo by Parks Canada of Melanie Spit on James Island, BC; photo by Ross Vennesland of pink sand-verbena at Clo-oose Bay, West Coast Trail, BC; photo by Nick Page of coastal strawberry in Cape Scott Provincial Park, BC; photo by Nick Page of American searocket community in Cow Bay, Vargas Island, BC; and photo by Parks Canada of South Bluff on James Island, BC. 

# Acknowledgements

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Appendix 2 lists a broader group of people that responded to a survey regarding the management of coastal sand ecosystems in BC.

# Summary


## Definition

Coastal sand ecosystems encompass the terrestrial portion of beaches, spits, and dunes in which sand is the dominant substrate. They contain sparsely-vegetated and herbaceous ecological communities, as well as associated forest, wetland, and bluff communities. They are structured by marine-related disturbance processes (e.g., sand movement, tides, storm surges, ocean spray), local climate, soil development, and vegetation succession.

## Distribution

Coastal sand ecosystems occur irregularly along marine shorelines in four areas of BC: (1) Georgia Basin (east coast of Vancouver Island and the Fraser River delta); (2) west coast of Vancouver Island; (3) central coast; and (4) Haida Gwaii (Queen Charlotte Islands). The total Extent of Occurrence (EO) of coastal sand ecosystems in BC is about 120,285 sq. km. They occur from the northwest tip of Graham Island to southern Vancouver Island, a distance of 940 km. Using an area-based assessment method, the Area of Occupancy (AO) for all (125) sites in BC was 2548.4 ha. This includes 60 sites in the Georgia Basin totaling 489.6 ha, 43 sites on the west coast of Vancouver Island totaling 245.1 ha, eight sites on the central coast totaling 24.4 ha, and 13 sites on Haida Gwaii totaling 1789.2 ha.

## Physical Context and Processes

Coastal sand ecosystems are the product of coastal climate, landscape processes, and geological history. Three geomorphic units are described: (1) sand beaches that encompass sloping shorelines composed predominantly of sand; (2) sand dunes which consist of wind-formed ridges and depressions found landward of the high water mark; (3) sand spits which are low-lying, linear to curved coastal features made of sand to gravel sized sediments formed by deposition of sediments in shallow water by wave and tidal currents with varying contributions of onshore sediment deposition by wind. Subtidal and intertidal sand bars are also discussed.

## Ecological Patterns and Processes

Coastal sand ecosystems in BC can be separated into three zones: (1) sparsely-vegetated lower beach zone defined by the lower limit of terrestrial plants; (2) upper beach zone with beach grass communities; and (3) sparsely-vegetated or stabilized dune zone. Many sand beaches and spits have only lower and upper beach zones, and the development of dunes is relatively rare in BC. Eight ecological communities have been described in coastal sand ecosystems in BC.

Most of the plant and animal species at risk in coastal sand ecosystems are associated with sparsely-vegetated ecological communities and the primary threat is the development of more stable and densely vegetated communities through accelerated succession. In BC, invasive plants, reduced sand supply from shoreline modifications, and atmospheric nitrogen deposition may contribute to accelerated succession.

## Species and Ecological Communities at Risk

Five species groups as well as ecological communities at risk in coastal sand ecosystems are discussed: (1) vascular plants; (2) bryophytes, lichens, and fungi; (3) vertebrates; (4) invertebrates; and (5) ecological communities. They include pink sand-verbena, contorted-pod evening-primrose, Streaked Horned Lark, Sand-verbena Moth, and Edwards' Beach Moth which are currently listed under the *Species at Risk Act* (SARA), as well as species or ecological communities that are of potential conservation significance. More rare species, particularly ground-based arthropods, moths, bryophytes, lichens, and fungi, will likely be identified from coastal sand ecosystems as more inventories are undertaken.

Four ecological communities in coastal sand ecosystems are currently considered rare in BC: (1) dune wildrye — beach pea Herbaceous Vegetation (S1S2, Red); (2) large-headed sedge Herbaceous Vegetation (S1S2, Red); (3) dune bluegrass Sparse Vegetation (S1, Red); and, (4) Pacific wormwood — red fescue — Racomitrium moss Herbaceous Vegetation (S1, Red). Others may be listed in the future.

## Threats

Seven threats to coastal sand ecosystems have been identified (in order of priority): (1) invasive plants; (2) disruption to coastal sediment transport; (3) recreation; (4) coastal development; (5) climate change; (6) invasive animals; and (7) atmospheric nitrogen deposition.

Many coastal sand ecosystems in BC have changed extensively over the past 100 years. An assessment of habitat change at six representative sites shows sparsely-vegetated habitats have declined from 35–95% in coastal BC since 1930. Rates of decline for species and ecological communities at risk are likely similar. Sites in the Georgia Basin have experienced greater loss of sparsely-vegetated communities than sites on the west coast of Vancouver Island and Haida Gwaii.

## Existing Protection or Other Status Designations

Overall, 85.6% of coastal sand ecosystems in BC are protected as park, with over 73.8% of the total area within provincial parks. The largest area is found in Naikoon Provincial Park in Haida Gwaii (1693.3 ha; 66.4% of total area in BC). Another 5.1% are federal or provincial Crown land including lands owned or managed by the Department of National Defence.

Portions of important coastal sand ecosystems on James Island are protected by a restrictive covenant, and the Nature Trust of British Columbia has a 50% undivided interest in a property on Savary Island that contains dunes and beach ecosystems.

## Special Significance

Coastal sand ecosystems are important for First Nations as sources of plant resources and other materials, or as sites for social gatherings, food processing, spiritual activities, or habitation. They are also important areas for hiking, camping, nature watching, and other forms of passive recreation, as well as for academic research to understand coastal processes and to reconstruct the geomorphic and glacial history of the BC coast. Finally, some coastal sand ecosystems protect adjacent houses, roads, agricultural lands, and other infrastructure from the effects of coastal flooding or storm damage.

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# Introduction

This report describes the distribution and ecology of coastal sand ecosystems in British Columbia (BC), and summarizes information on rare species and ecological communities. Its purpose is to provide a foundation for ecosystem-based recovery planning to conserve species and ecological communities in coastal sand ecosystems. This report provides information on geomorphology, coastal processes, ecological patterns, species and ecological communities, ethnoecology, threats, and ecosystem trends to improve the collective knowledge about these ecosystems, and to assist with recovery planning. The report also identifies research priorities to address knowledge gaps about species or species groups such as arthropods, moths, lichens and bryophytes that are poorly understood. In general, coastal sand ecosystems in BC are not well studied relative to forested, grassland, or meadow ecosystems.

Coastal sand ecosystems encompass the terrestrial portion of beaches, spits, and dunes in which sand[1] is the dominant substrate. They contain sparsely-vegetated or herbaceous ecological communities, as well as associated forest, wetland, and bluff communities. Coastal sand ecosystems occur at the intersection of marine and terrestrial realms where ecological patterns are structured by geomorphic and oceanographic disturbance processes (e.g., sand movement, wind erosion, tides, storm surges, ocean spray), soil development, local climate, and vegetation succession. This report focuses on the terrestrial zone[2] and excludes the intertidal zone, which is inundated by tidal waters daily and is ecologically distinct. Some wetland and forest communities that are closely associated with sand ecosystems including Sitka spruce, shore pine or Douglas-fir forests on ancient dune fields, coastal meadows in moist sandy backshore sites, salt marsh on the leeward side of many spits, and shrub communities on eroding bluffs are considered associated ecosystems, but are not discussed in detail in this report.

Coastal sand ecosystems contain a number of species of conservation significance that are adapted to the unique environmental conditions in sandy habitats. Most rare species are associated with sparsely-vegetated communities in sand dunes or beaches. Noteworthy species at risk in coastal sand ecosystems include pink sand-verbena, contorted-pod evening-primrose, silky beach pea, Streaked Horned Lark, Sand-verbena Moth, and Edwards' Beach Moth. More rare species, particularly ground-based arthropods, moths, bryophytes, lichens, and fungi will likely be identified from coastal sand ecosystems as more research is undertaken.

1 Sand is composed of coarse particles between 0.0625–2 mm in size. Sand is larger than silt (0.004–0.0625 mm) and clay (<0.004 mm) and smaller than gravel (2–64 mm). In coastal BC, most sand is composed of angular quartz (silicon oxide) and aluminum oxide particles with minor amounts of shell debris. Quadra Sand is the dominant sand material in the Georgia Basin (Clague, 1977).

2 The lower boundary of the terrestrial backshore and the upper boundary of the intertidal zone is defined by the high water mark. This is the average elevation of high tides over an extended period of time.

# Distribution

Coastal sand ecosystems occur irregularly along marine shorelines in four areas of BC: (1) Georgia Basin (east coast of Vancouver Island, Gulf Islands, and the Fraser River delta); (2) west coast of Vancouver Island; (3) central coast; and (4) Haida Gwaii (Queen Charlotte Islands) Figure 1 and Appendix 4. Sites are similar in form and character within these regions, particularly in the structure and composition of ecological communities. They also share similar physical environments because of the underlying influence of surficial geology, coastal sediment transport processes, and climate in shaping coastal sand ecosystems.

**Extent of Occurrence.** The total Extent of Occurrence (EO)[3] of coastal sand ecosystems in BC is approximately 120,285 sq. km. They occur from the northwest tip of Graham Island to southern Vancouver Island, a maximum linear distance of 940 km.

***Area of Occupancy.*** Using an area-based assessment method, the Area of Occupancy (AO) for all (125) sites in BC was 2548.4 ha. This includes 60 sites in the Georgia Basin totaling 489.6 ha, 43 sites on the west coast of Vancouver Island totaling 245.1 ha, eight sites on the central coast totaling 29.5 ha, and 13 sites on Haida Gwaii totaling 1784.2 ha.

## Georgia Basin Sites

Coastal sand ecosystems in the Georgia Basin typically consist of eroding bluffs of sands deposited by glacial outwash paired with a depositional feature such as a spit or sand bar. Feeder bluffs are typically located to the south of depositional features with sands transported by prevailing southwest wind waves in the Strait of Georgia (see Figure 2 for an example near Sidney, BC). There are approximately 69 km (covering about 369 ha) of active or semi-active sand bluffs in the Georgia Basin. Intervening beaches function as transport features but typically neither supply nor accumulate sands between source and deposition areas. Windblown dunes are rare in the Georgia Basin. Remnant stabilized dunes occur in the Cape Lazo area near Comox, and on Savary Island (Clague *et al*., in press). Wind influences sand movement in additional Georgia Basin sites (e.g., Goose Spit, Cordova Spit, Savary Island) but active dune forms are typically not present. Coastal sand ecosystems are very rare in the Fraser River Delta area and other parts of the lower mainland coast. The largest site is the western shore of Boundary Bay where an extensive series of relict sand spits are present in Boundary Bay Regional Park. These spits developed from eroding bluffs along the east and southeast shores of Point Roberts. Some active sand movement still occurs in this area but most of the spit complex is enclosed by shoreline dikes. A second coastal sand site is located in Iona Island Regional Park. The site is composed of silty sand which originated as material dredged from the North Arm of the Fraser River and supports several sparsely-vegetated ecological communities including bryophyte-dominated communities that have been colonized by Scotch broom and grasses (see Hanna, 2008). There are several active erosion sites along the Point Grey bluffs which provide sand to Spanish Bank along the western shore of English Bay.

3 Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a taxon, excluding cases of vagrancy.

Prominent examples of coastal sand ecosystems in the Georgia Basin with feeder bluffs and large depositional features are:

- Cowichan Head Bluffs ❯ Island View Beach and T̸IX̱EṈ (Cordova Spit)
- James Island Bluffs ❯ Melanie, Village, and Powder Jetty Spit
- Komas Bluff (northeast Denman Island) ❯ Longbeak Point, Sandy Island, and islets
- Willeman Bluff (Comox) ❯ Goose Spit
- Savary Island ❯ South Beach Bluff (and other bluffs)
- Cape Mudge Bluff (Quadra Island) ❯ Rebecca Spit
- Point Roberts Bluff (US) ❯ Boundary Bay spit complex

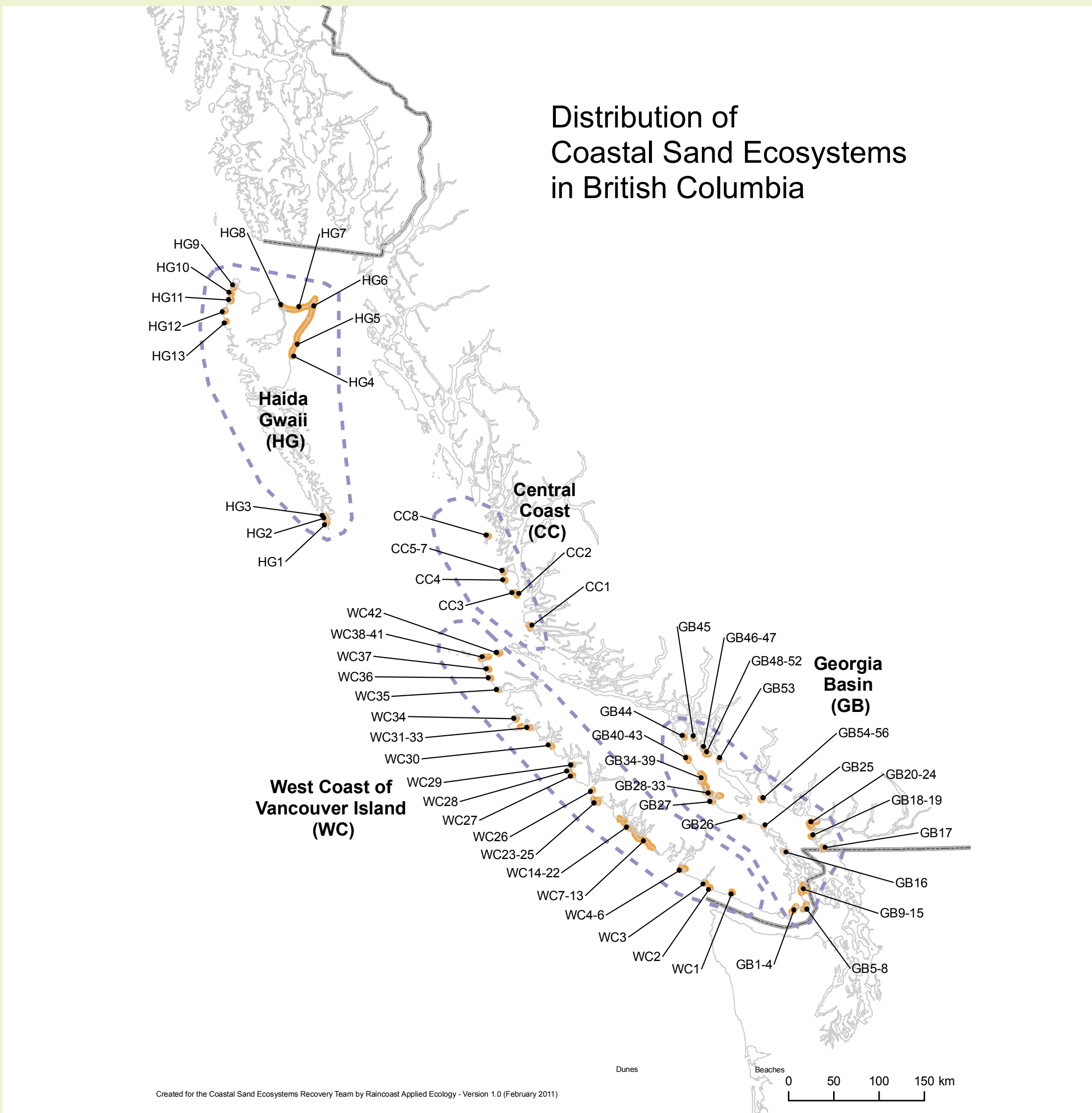


**FIGURE 1.** DISTRIBUTION OF COASTAL SAND ECOSYSTEMS IN BC. A key to the name codes on the figure is provided in Appendix 4.

Figure 2 provides an overview of feeder bluffs and their associated accretional features on Sidney Island, James Island, and the shoreline of the Saanich Peninsula (Cowichan Head, Island View Beach, and Cordova Spit). Figure 3 shows examples of coastal bluffs and their associated accretional features in Georgia Basin. A total of 60 coastal sand ecosystem sites were identified in the Georgia Basin occupying 489.6 ha; approximately 50% have some form of protection (park, conservation covenant) (Table 2). However, only about 271 ha (38%) are sparsely-vegetated or open sand communities.

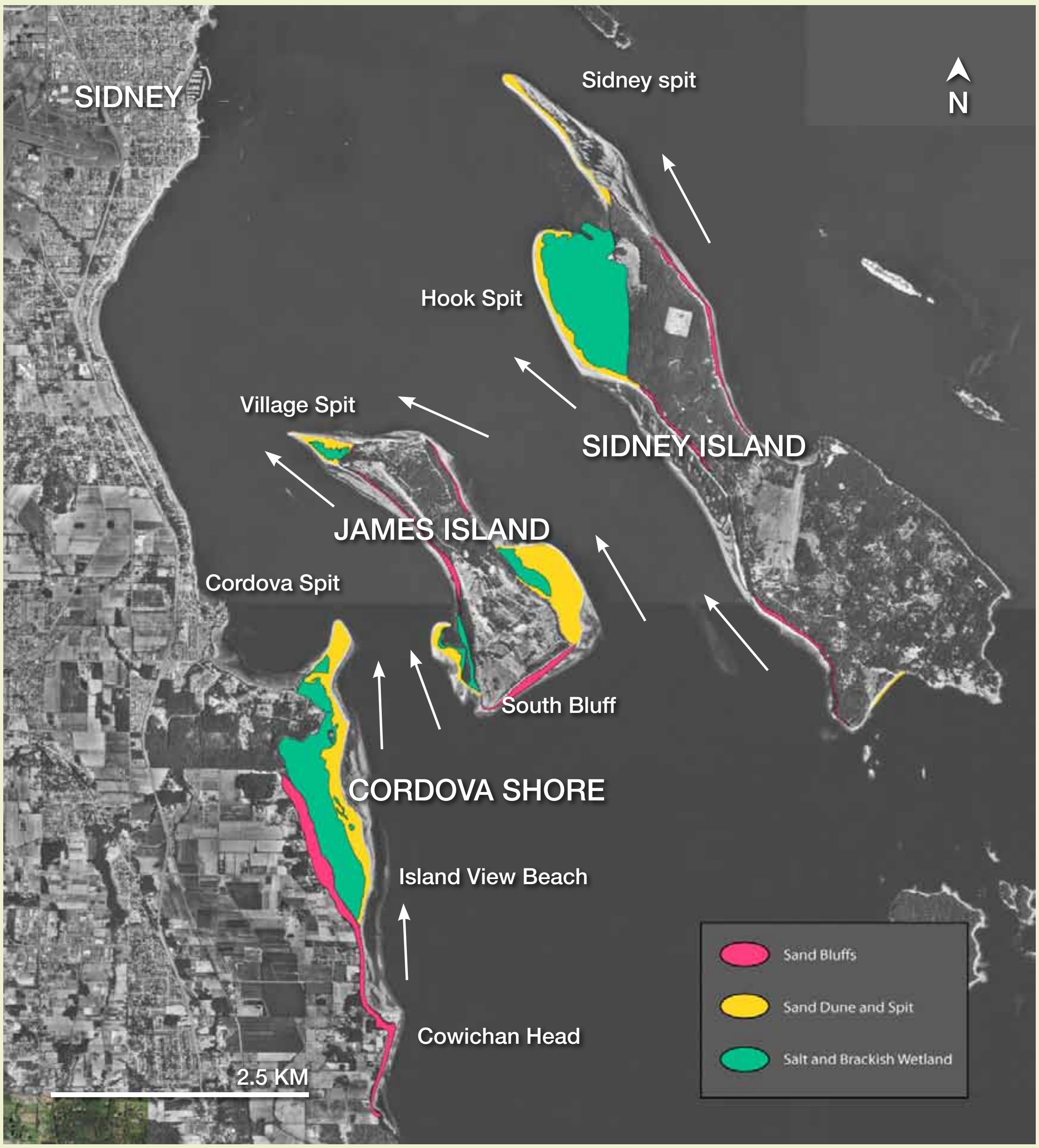


**FIGURE 2.** SAND BLUFFS, DUNES, SPITS, AND COASTAL WETLANDS IN THE CORDOVA SHORE-JAMES ISLAND-SIDNEY ISLAND AREA OF SOUTHERN STRAIT OF GEORGIA. Feeder bluffs are shown in red, coastal sand ecosystems are shown in yellow, and coastal wetlands are shown in green. The prevailing direction of sediment transport is shown with white arrows (from the south and southeast).

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**FIGURE 3.** MOST OF THE FEEDER BLUFFS IN THE GEORGIA BASIN ARE COMPOSED OF QUADRA SAND inter-bedded with gravel and silt and overlain with glacial till. Representative examples are: (a) Komas Bluff on the northeast side of Denman Island which provides sand to Sandy Island; (b) Savary Island bluffs; (c) Willemar Bluffs in Comox which provides sand to Goose Spit (background); and d) southern bluff on James Island. Photo a by A. Fyson; b (unknown author); c by A. Mewett; and d by Parks Canada.

## West Coast of Vancouver Island Sites

Coastal sand ecosystems along the west coast of Vancouver Island are typically large embayed beaches with a well-developed terrestrial backshore. Dunes are relatively uncommon and spits are very rare, given highly energetic wind and wave conditions, although Clayoquot (Stubbs) Island near Tofino has a broad, wedge-shaped sand spit (see Figure 4) and Benson Point (see Figure 4) has a sand tombolo. Sand sources for west coast Vancouver Island beaches are poorly understood compared to Georgia Basin sites. Most of the sand moved into large beaches is either from shallow subtidal deposits of glacial origin or reworked terrestrial deposits delivered by rivers. Terrestrial sources of sand from eroding bluffs are rare and the only prominent bluff is Florencia Bay in Pacific Rim National Park Reserve.

Sites are concentrated from the Bamfield area south of Barkley Sound (Pachena Bay and Keeha Bay) to the Hesquiat Peninsula at the northern margin of Clayoquot Sound (Wickaninnish Beach, Schooner Cove, Ahous Bay (Figure 4), Clayoquot Island (Figure 4), Cow Bay, and Hesquiat Harbour). Important sites on southwest Vancouver Island include the dunes at Cheewhat Bay (Clo-oose) and Keeha Beach, and the coarse sand beach at Port Renfrew. On northwest Vancouver Island, prominent coastal sand ecosystems include Barchester Bay (northside of Hesquiat Penisula), Benson Point (Figure 4), Driftwhale Bay (Brooks Peninsula), Grant Bay, Raft Cove, San Juan Bay, and Guise Bay (Cape Scott). Most of these sites lack sparsely-vegetated dune habitats, and only at Guise Bay are dunes well developed. Many smaller sand beaches occur along the west coast of Vancouver Island but most are too small to support well developed backshore or dune habitats and the species at risk associated with them. Many only support species-poor plant communities composed of American searocket *(Cakile edentula)*, seabeach sandwort *(Honckenya peploides)*, beach pea *(Lathyrus japonicus)*, and dune wildrye *(Leymus mollis)*.


**FIGURE 4.** EXAMPLES OF LARGE COASTAL SAND ECOSYSTEMS ON THE WEST COAST OF VANCOUVER ISLAND: a) large crescent beach at Ahous Bay on Vargas Island (note older beach ridges visible in wetland complex in lower portion of photo); b) sand tombolo at Benson Point northeast of Nootka Island; c) small dune blowout on Keeha Bay west of Bamfield (Pacific Rim National Park Reserve); and d) sand spit at Clayoquot (Stubbs) Island near Tofino. Photos b and c by N. Page; photos a and d by Province of BC.

## Haida Gwaii and Central Coast Sites

Sedimentary (gravel to sand) beaches comprise approximately 31% (~1337 km) of Haida Gwaii's shoreline, which is proportionately high compared to the rest of the BC shoreline (Walker, 2006). Most of the coastal sand ecosystems in Haida Gwaii exist on the northern and eastern shores of Graham Island — the largest and northernmost island in the archipelago. Most notable are the exposed beaches of East Beach from Tlell to Rose Spit. This stretch of coast hosts magnificent eroding bluff systems (e.g., Cape Ball and Cape Fife) and extensive dune systems including stablized dune ridges dating back to ~7,000 BP (Wolfe *et al*., 2008). On the northern shore exists prograding, foredune backed beaches from Rose Spit to Masset and at Lepas Bay on northwestern Graham Island near Langara. Significant embayed beach-dune systems also exist in southern Haida Gwaii, such as at Woodruff and Gilbert bays on Kunghit Island. Due to the erodible substrate, exposure to extreme waves and ongoing sea-level rise, this shoreline is one of Canada's most sensitive to climate change-induced sea-level rise (Shaw *et al*., 1998; Walker and Barrie, 2006, Walker *et al*., 2007).

## Distribution and Geology of Large Sand Deposits

Coastal sand ecosystems are closely tied to glacially-derived sand deposits and this section provides a brief introduction to their origin and distribution in coastal BC.

All large coastal sand ecosystems in the Strait of Georgia are associated with occurrences of glacially-deposited sand, either Quadra Sand or related deposits such as the Cowichan Head Formation near Victoria. Quadra Sand consists of a 5–50 m layer of coarse and medium sand deposited in thick layers (30 to >100 m) during the initiation of the last glacial period. Sites near the northern end of the Strait of Georgia (e.g., Savary Island) are around 29,000 yrs BP, and around 10,000 yrs BP in the south. Quadra Sand is noteworthy because of its uniformity with little inter-bedded layers of coarser or fine materials. Cowichan Head Formation is an older deposit but is similar to Quadra Sand in composition. Important sand deposits in the Georgia Basin include the Cape Lazo area near Courtenay, Cape Mudge at the southern end of Quadra Island, Point Grey bluffs in Vancouver, as well as Savary, Hernando, and Marina islands (see map from Clague *et al*. (2005) showing the distribution of Quadra Sand in the Georgia Basin in Appendix 1).

The occurrence and origin of sand deposits on the west coast of Vancouver Island is less well understood. While they are also glacial deposits, eroding feeder bluffs are uncommon and most sand supplied to sand beaches and dunes is stored in shallow off-shore deposits. The large eroding bluff in Florencia Bay composed of sandy gravel and silt is the only prominent bluff on the west coast of Vancouver Island. Some of the sediment stored in off-shore deposits is likely fluvial in origin. Some of the sand which has formed the Wickaninnish Beach dunes, for example, is supplied by erosion in the Sandhill Creek basin.

The northeast corner of Graham Island (Haida Gwaii) contains a large sand and gravel deposit that is similar in texture, structure, and minearology to Quadra Sand (Clague, 1977). Geologically, this 600 sq. kilometer area formed as a glacial outwash plain (sandur) at the terminus of glaciers as they re-advanced during the last glacial period. Reworking of this material by wind and waves forms the prominent sand beaches and dunes at Rose Spit.

# Physical Context and Processes

More than any other ecosystem in BC, coastal sand ecosystems are the product of their coastal landscape, climate, and geological history. They are intrinsically tied to the movement of sand by waves and winds from eroding bluffs and shallow marine sand deposits, and form and sustain beaches, spits, and dunes. Coastal sand ecosystems reflect thousands of years of coastal processes. Because of this connection, this report emphasizes the importance of understanding physical coastal processes that sustain coastal sand ecosystems.

## Physical Processes

Wave swash and uprush inundate the intertidal foreshore. The range and extent of this depends on beach slope, wave conditions, and tidal range (e.g., micro, meso, or macro) and stage in the cycle (e.g., neap vs. spring). Additional beach inundation can occur during storm surges, where extra water elevation is generated regionally by drop in atmospheric pressure and wind shear of water over long distances. Storm surges on the order of 10 cm to a metre are common during fall and winter storms on the BC coast.

Onshore aeolian (windblown) sediment transport is an important component of many coastal sediment budgets. The prevalence of aeolian action, as a significant agent in coastal sediment dynamics, depends upon:

- frequency, magnitude, and directionality of winds above the sand transport threshold (typically >6 m/s);
- availability of sand-sized sediment;
- moisture content of the substrate and/or precipitation;
- vegetation cover; and
- stage of the tide.

On sandy beaches, tide stage and wind direction are important as they control the effective distance for aeolian sand transport (Bauer and Davidson-Arnott, 2006). Despite a wet climate and dense vegetation on most of the sandy shorelines in Haida Gwaii, onshore aeolian sand transport is high, particularly along the northeast Graham Island coast (Walker and Barrie, 2006).

The backshore zone of coastal sand ecosystems is an inherently dynamic biophysical system that is responsive to environmental changes such as coastal erosion/sedimentation, ecological succession, invasive species, land use change, and climate variability and change. Ultimately, these changes are expressed in beach and dune geomorphology and ecological composition. That said, it is often difficult to distinguish between natural changes such as dune succession and anthropenic changes without careful examination of change over appropriate space and time scales. Typically, this requires study of biophysical and geomorphic relations on larger spatial ranges (e.g., 10s km) and longer time spans (decades to centuries) than that of single dune or beach sites over a few years.

Compared to the eastern shores of Canada and the United States, there has been relatively little research on sandy coastal systems in BC. Although they represent a relatively small proportion of BC's coastline, they are host to a variety of specialized ecosystems and threatened species, and they are sought after locations for recreation, cultural use, and developmental purposes. Also, given their exposure to the Pacific Ocean, coastal sand ecosystems are exposed to increasing storms and sea-level rise with climate variability and change, and infrequent tsunami events.

## Definitions

A shoreline is essentially the point where water and land meet on a beach. In tidal areas, the shoreline will fluctuate from the lowest to highest tide elevations. For mapping and some legal/jurisdictional purposes, the high water mark is often used. This is often indicated by some natural line or feature on a beach such as an erosional scarp, the toe of a foredune, or limit of terrestrial vegetation. The intertidal area below the high water line is known as the foreshore and the supratidal area above it is known as the backshore. The subtidal zone from the low tide mark to the point of wave shoaling is known as the nearshore.

**Sand beaches** encompass sloping shoreline areas that are predominantly sand (but occasionally intermixed with gravel and/or cobble), whose form is defined by the movement of sand by wave swash, nearshore currents, and winds on the upper beach. Larger beaches often have a storm berm (a low backshore ridge; Figure 5) that reflects the highest landward extent of storm wave action. Examples of sand beaches in coastal BC include Crescent Beach in Delta, Wickaninnish Beach in Pacific Rim National Park Reserve, Island View Beach in Sidney, Kye Bay Beach in Comox, Savary Island, and Rathtrevor Beach.

**Sand dunes** are terrestrial sand ridge features that are found landward of sand beaches in coastal areas (Figures 5 and 6). Dunes are formed by the movement of sand by wind (aeolian transport). Coastal foredunes are dune ridges that form at the back of the beach due to onshore aeolian sand transport and are often vegetated with beach grasses. Dunes may be active (sand movement occurs at present) or remnant or stabilized (sand movement occurred in the past). Given the low percentage of sandy shoreline in BC, sand dunes are inherently sparse in occurrence. Examples include active dunes along East and North Beaches near Rose Spit on Haida Gwaii, Wickanninish Beach and Schooner Cove in Pacific Rim National Park Reserve, Cape Scott on NW Vancouver Island, Naikoon Provincial Park on NE Graham Island (Haida Gwaii), Gilbert and Woodruff bays in Gwaii Haanas National Park Reserve and Haida Heritage Site, Savary Island, and stabilized dunes near Cape Lazo at Comox.

**Sand spits** are linear to curved coastal features made of sand that are formed by the deposition of sediment into shallow water (see cover photos). They are attached at one end to a larger terrestrial land mass. Their form is controlled by the movement of sand by waves and nearshore currents. Examples of sand spits include Goose Spit at Comox, T̸IX̱EṈ (Cordova Spit) near Sidney, Witty's Spit in Metchosin, and Rose Spit on NE Graham Island.

**Sand bars** are sub-tidal to intertidal sand ridges that are formed by wave action and nearshore currents. They can extend from the intertidal beach (shore-attached) or exist in the subtidal nearshore, where they often cause wave shoaling. Bars can be shore-parallel, oblique, or crescentic in form, depending on wave climate, tidal currents, and nearshore currents (e.g., offshore rips, alongshore). Sand bars can move (migrate) and change their form, spacing, and proximity to the beach with seasons and/or in response to large storm events. Sand bars are an important store of sand in the intertidal to nearshore zones that may replenish beach and/or dune systems as they move alongshore and/or on-offshore during their migration. Sand bars can be found at Sidney Spit/Hook Spit, Witty's Lagoon, Kye Bay, Miracle Beach, Goose Spit, northern Denman Island, and Rathtrevor Beach Provincial Park (Figure 5).

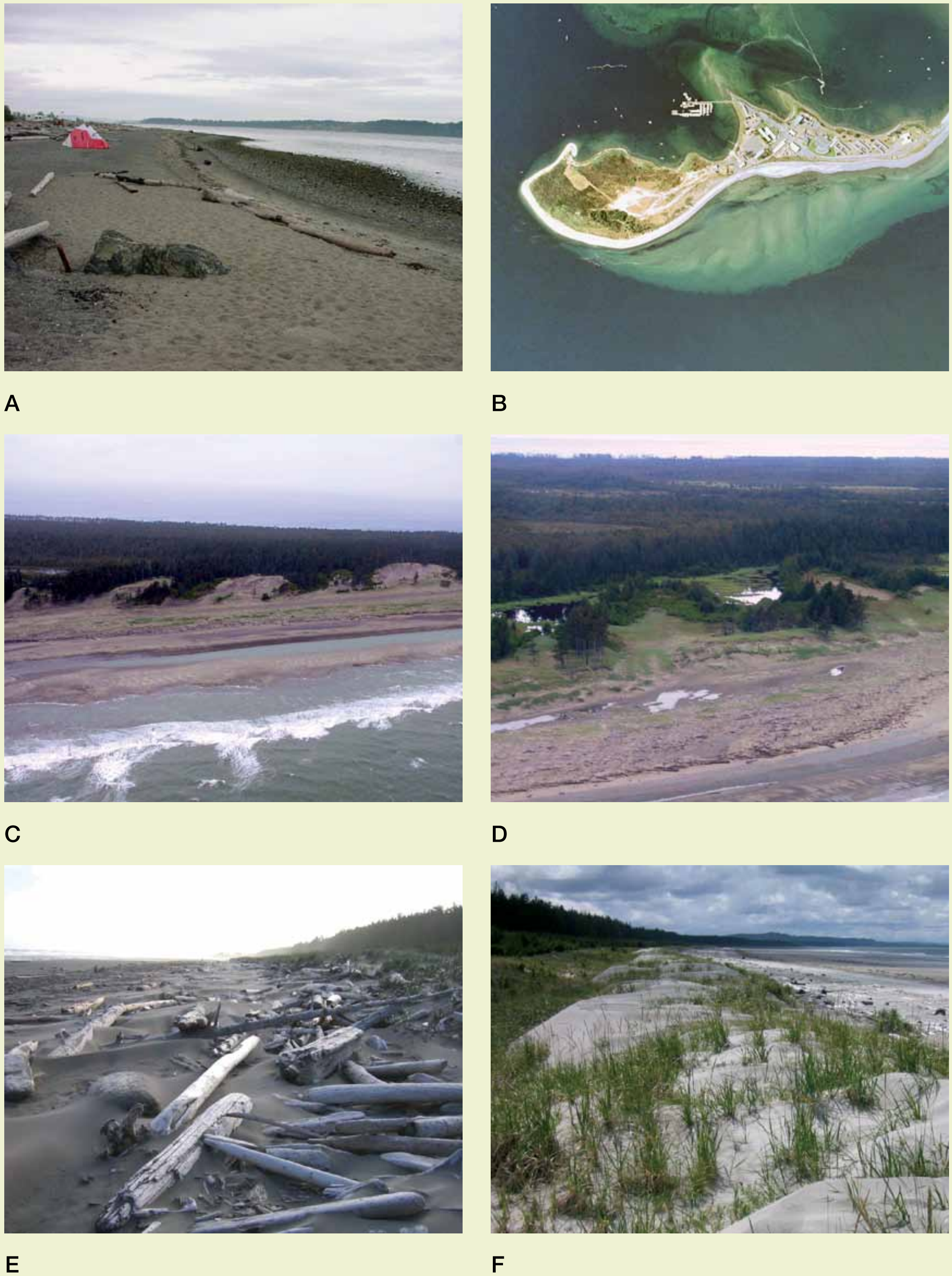


**FIGURE 5.** REPRESENTATIVE GEOMORPHIC FEATURES IN COASTAL SAND ECOSYSTEMS: a) low winter storm berm located landward of log debris, Island View Beach, BC; b) nearshore bar (Goose Spit); c) large blowout dunes backing East Beach near Rose Spit, Haida Gwaii; d) two small (~100 m wide) parabolic dunes migrating inland, East Beach, Haida Gwaii, BC. Note that the arms and head of these dunes are heavily treed, while the central deflation basin is vegetated by grasses; e) incipient foredune forming in log debris, South Beach, Haida Gwaii, BC; f) accreting foredune, South Beach, Haida Gwaii, BC; Photos by Ian Walker.

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**FIGURE 6.** REPRESENTATIVE GEOMORPHIC FEATURES IN COASTAL SAND ECOSYSTEMS (continued): a) established foredune with small incipient dune, Schooner Cove, Pacific Rim National Park Reserve; b) established foredune heavily vegetated with invasive beachgrass fronted by incipient foredune, Wickanninish Beach, Pacific Rim National Park Reserve; c) intertidal gravel swash bar atop a sand beach formed during storm waves, Naikoon Provincial Park, BC; d) active dunes, Wickanninish Beach; e) well-developed foredune ridge (Whaler Islet); and f) dune at Guise Bay, Cape Scott Provincial Park. Photos a to c by Ian Walker, d to f by N. Page.

## Coastal Geomorphology

Beaches are dynamic features that are shaped by wind, wave, and tidal processes as well as sediment supply conditions. As each of these processes have their own cycles and extremes, beaches constantly change their form and sedimentology. For instance, in the winter, many beaches appear steeper and coarser as finer sediments are removed by strong winter winds and waves. In contrast, summer beaches may appear flatter and finer as lesser summer waves move finer sands onshore that were removed during the winter. Thus, what is seen on a beach at a given point in time may be in balance with some processes (e.g., wave swash, tides) but out of phase with others (e.g., winter storms). For this reason, beaches are viewed as inherently dynamic systems that constantly change their form. As such, erosion and sedimentation are also natural responses of beaches as they adjust to seasonal or interannual changes in weather and ocean conditions. Sediment transport rates are often discontinuous and wedges of sand move in pulses along shorelines.

Shoreline stability (i.e., unchanging position) depends on sediment supply, wave/tidal energy and, importantly, timescale. In most coastal areas in Canada, the shoreline we see today is likely not as it was a few hundred or a few thousand years ago. In fact, sea level in BC has fluctuated by more than 100 m relative to modern levels over the past 10,000 years due to changing amounts of water in the ocean and to movements of the Earth's crust following glacier retreat after the last ice age. Even during historical times, shorelines have moved in Canada due to relative sea-level changes. For instance, historical buildings in eastern Canada are submerging during high tides as the Earth's crust continues to sink due to crustal flexure that is still ongoing since the last ice age, whilst the ocean rises due to global warming effects. In other areas, new land is created as beaches grow seaward while sea levels fall. Such changes in relative sea level occur when the land elevation and/or the ocean levels change resulting in a shift in shoreline position. Globally, mean sea level increased 10 to 20 cm during the 20th century, and is anticipated to rise another 18 to 59 cm by 2100, due largely to melting glaciers and ice sheets, and thermal expansion of warming seawater (IPCC, 2007). In BC, relative sea-level change differs from the global trend due to vertical land movements. During the twentieth century, sea level rose 4 cm in Vancouver, 8 cm in Victoria and 12 cm in Prince Rupert, and dropped by 13 cm in Tofino (BC Ministry of Water, Land and Air Protection, 2002; Walker and Sydneysmith, 2008; Abeysirgunawardena and Walker, 2008).

A shoreline is stable if its position does not change over some defined time period. This occurs typically when sediment supply is sufficient and erosive high water events are infrequent. If sediment supply is plentiful and a beach receives more sediment than it loses, it is accreting. In response, sediment may accumulate (sedimentation) in new or existing sand bars, dunes, and/or beach ridges. Over time, sediment accretion may cause the shoreline to advance seaward — a process known as progradation. For instance, North Beach on NE Graham Island has prograded several hundred metres seaward over the past 3000 years by foredune and/or beach ridge growth. The modern rate of progradation is currently 0.3 to 0.7 m/yr (Wolfe *et al*., 2008).

Erosion is when a net loss of material (usually sediment) occurs from a beach system over a defined time period. Sediment transport, in itself, is not erosion unless there is a net sediment loss from the beach. In response to erosion, a shoreline may retreat landward. For example, some areas of East Beach in Naikoon Park, NE Graham Island have retreated at 1–3 m/yr over the past few decades and more rapidly (10s m/yr) in response to extreme events (Walker and Barrie, 2007). Erosional features common on beaches include scarps or bluffs — typically steep-faced, exposed sedimentary slopes formed by wave undercutting that can range from 10s of cm to 10s of metres (e.g., Cape Ball, NE Graham Island or the east facing bluffs of Sidney Island). River outflows may also cause incised channels in beaches that may have developed over tidal cycles, seasons, or hundreds of years as the elevation of the river system relative to the ocean changes in response to sedimentation and/or sea-level changes.

Both erosion and accretion can occur very gradually. Erosion is often most noticed, however, in response to episodic events such as big storms. When subjected to waves and storm surges, most beaches will erode and their sediment will move seaward. Often this sediment is stored in nearshore bars or it moves along the beach in strong nearshore currents. If stored in bars, this sediment may return to the beach during less energetic wave conditions (e.g., summer). If moved in nearshore currents, the sediment can travel great distances and may never return to the beach from which it was removed. For instance, much of the sediment that now forms Rose Spit on NE Graham Island in Haida Gwaii derived from eroding bluffs at Cape Ball, nearly 40 km to the south, and transported northward by strong tidal current (Amos *et al*., 1995).

Sandy coastal systems are host to a suite of landforms in the nearshore, foreshore, and backshore (some defined above) that reflect the exchanges between sediment supply and wind, wave, and tidal action. Coastal sediments are delivered to the beach via wave swash and nearshore currents. Wind-transported (aeolian) sands are an important and often overlooked component of the coastal sediment budget. These finer sands (i.e., < 1 mm) are reworked from the foreshore and transported within and beyond the backshore by competent winds (i.e., >6 m/s) where they may accumulate in the presence of vegetation, flotsam, or log debris. These structural features form incipient (or embryo) dunes that may be seasonal in nature. Over time, as more sediment accumulates, incipient dunes can grow and may become colonized by backshore vegetation to form established dunes. As such, coastal dunes are formed exclusively by windblown sand transport.

The most common type of coastal dune is a foredune — a shore-parallel, vegetated dune ridge that backs a beach. Foredunes are commonly vegetated with grasses such as dune wildrye or European beachgrass (*Ammophila* spp.). Established foredunes can reach 10–15 m in height and are commonly vegetated with various tree species including Sitka spruce *(Picea sitchensis)*, shore pine *(Pinus contorta)*, western hemlock *(Tsuga heterophylla)*, and red alder *(Alnus rubra)*.

Foredunes act as important stores of sediment that buffer or protect shorelines against wave attack, storm surge flooding, and gradual sea-level rise (Walker and Barrie, 2007). Examples are found along East and North beaches in Naikoon Provincial Park on Haida Gwaii and backing Wickanninish Beach and Schooner Cove in Pacific Rim National Park Reserve. Other types of coastal dunes include: 1) u-shaped parabolic dunes with vegetated arms that often extend landward from established foredunes (e.g., Naikoon Park, NE Graham Island), 2) coppice dunes — vegetated sand hummocks that form in/around shrub or treed vegetation clusters (e.g., Wickanninnish Dunes, Pacific Rim NPR), and 3) erosional saucer- or elongated trough-shaped blowouts often found superimposed on other established dune forms.

Given the dynamic nature of sand dunes as windblown forms, they have a tendency to move, or migrate. This is a natural process that occurs as dunes adjust to changes in wind strength and direction, sand supply, and/or changes in surface vegetation cover. Migration can be exacerbated by human activities (e.g., deforestation, vegetation removal, excessive vehicle or human traffic) or can be inhibited by use of sand fences, introduction of non-native vegetation, or disruption of sand supply. Landward foredune migration is thought to be an important and required response to allow sandy, dune-backed shorelines and related backshore ecosystems (including wetlands) to keep pace with sea-level rise (Davidson-Arnott, 2006).

Log debris jams are very common to beaches in BC. Largely composed of felled timber, this debris and other flotsam act as an important accretion anchor for coastal sediments in the backshore (Walker and Barrie, 2007; Eamer and Walker 2010). By extracting wind energy, log debris causes wind-transported sand to be deposited. Sand accretion occurs very rapidly and, provided a high erosive water level event does not remove the debris, new incipient dunes can develop in the backshore. Incipient dunes can also develop on the beach in the absence of driftwood via beach vegetation colonization (Hesp, 1989). Many stabilized modern foredunes in BC are filled with log debris, which can be seen on recently eroded beaches. This is a testament to the important historic role that logging debris has played in beach sedimentation. Examples can be found at Wickanninish Beach and Naikoon Provincial Park. Though often considered beach ‘trash’, driftwood plays a very important role in trapping and storing beach sediments that otherwise may not have deposited in the backshore. This sediment increases the buffering capacity of the shoreline against wave attack and also provides new sites for vegetation colonization.

## Soils

Beaches and dunes have undeveloped or young soils (regosols) that are composed of sand with small amounts of silt, clay, and organic matter. They are typically nutrient-poor, salt-rich (particularly in the lower beach zone), and have little moisture holding capacity because of the lack of fine particles or organic matter. Summer drought is common and infertility is caused by the lack of both nitrogen and phosphorous and, to a lesser extent, potassium (Maun, 2009)

A B

**FIGURE 7.** EXAMPLES OF SOIL DEVELOPMENT IN COASTAL SAND ECOSYSTEMS: a) organic-rich sand soil developed beneath moss, grass, and Scotch broom plant community on older dunes at Goose Spit; and b) dune podsol, Naikoon Park, BC. Photo a by N. Page and b by Ian Walker.

In coastal climates with high precipitation, sand soils experience rapid leaching, acidification, and podsolisation, because of high permeability and low acid buffering capacity (Sevink, 1991). Podsols are typically found on older stabilized or relict dune features and are typically characterized by a relatively thin, dark A horizon (topsoil) underlain by a strongly bleached Ae horizon (zone of maximum leaching) and, often, a distinct, hard B horizon where leached iron and/or clays accumulate. If drainage is poor, organic matter will accumulate in the sand and peat formation may result. An example of a well developed dune podsol is shown in Figure 7 from Naikoon Provincial Park on Haida Gwaii. Sediment from 1 m depth in this soil profile was dated to 340 years BP using optical dating techniques (Wolfe *et al*., 2008). This was a time when this dune feature was active and in close proximity to the shoreline. This sampling location is now several km distant from, and over 10 m above, the modern shoreline.

In sand beaches and dunes on the west coast of Vancouver Island, Page (2003) found strong spatial gradients in soil chemistry from the intertidal zone to the forest edge. pH declined rapidly from greater than 8.0 near the shore to less than 6.0 approximately 50 m inland. Nonparametric regression indicated that there was little change in pH between the mid-point of the 100 m spatial gradient and the open dunes further inland. pH declines as calcium carbonate derived from seawater is leached by soil weathering and is replaced by hydrogen and aluminum ions (Etherington, 1976). It stabilizes near 5.5 because of the buffering capacity of aluminum ions. Cordes (1972) found pH ranged between 4.3 and 4.8 in forest soils along the coastal fringe in the same study area, which likely indicates the end-point for soil development on beach sands.

Specific conductivity followed a similar pattern as pH; it reached a maximum of approximately 170 uS/cm near the shoreline and declined to less than 50 uS/cm in the dunes near the forest edge. This relationship was also not statistically significant. Other studies have shown that ion enrichment from ocean spray, principally from sodium and chloride ions, declines as precipitation-induced leaching increases inland from the shoreline (Cordes, 1972; Gerlach *et al*., 1994; Wilson and Sykes, 1999).

Page (2003) also found that percent total soil carbon and percent total soil nitrogen showed a significant unimodal relationship with distance from the shore; maximum values are associated with the grass-dominated upper beach with nutrient-poor soils characterizing both the lower beach and dunes. Similarly, mean values of plant species richness and total plant cover showed a significant unimodal relationship with distance. Coastal sand ecosystems are nitrogen-limited infertile environments (Vitousek *et al*., 1997). Nutrients from coastal inputs, vegetation decomposition, or biological fixation are rapidly leached from sand soils by high winter precipitation (Olson, 1958; VandenBygaart and Protz, 1995). Soil infertility is an important factor in the development of sparsely-vegetated communities, and also a limitation on the rate of successional change. It also makes coastal sand ecosystems sensitive to nutrient enrichment from atmospheric deposition or nitrogen-fixing invasive plants.

## Climate

Coastal sand ecosystems in BC have strongly maritime climates characterized by warm, dry summers and cool, wet winters. Georgia Basin sites have a more moderate climate with drier summers, influenced by their location in the rainshadow of the Vancouver Island mountains, while sites on the west coast of Vancouver Island, central coast, and Haida Gwaii are wetter and cooler. For context, climate data from five sites from throughout coastal BC are presented in Table 1.

**Table 1. Mean monthly and annual climate data for representative sites in coastal BC.**

| Variable | Vancouver | Comox | Tofino | Cape Scott | Tlell |
|---|---|---|---|---|---|
| Mean Daily Temperature | 10.1˚C | 9.7 ˚C | 9.1 ˚C | 8.9 ˚C | 7.7 ˚C |
| Mean Summer[1] Monthly Temp. | 16.8 ˚C | 16.7 ˚C | 13.8 ˚C | 12.8 ˚C | 13.3 ˚C |
| Mean Winter[2] Monthly Temp. | 3.9 ˚C | 3.5 ˚C | 4.8 ˚C | 5.2 ˚C | 2.7 ˚C |
| Annual Precipitation | 1199.0 mm | 1179.0 mm | 3305.9 mm | 2650.6 mm | 1242.0 mm |
| Mean Summer Monthly Precip. | 44.5 mm | 36.2 mm | 102.9 mm | 102.7 mm | 58.4 mm |
| Mean Winter Monthly Precip. | 150.8 mm | 160.7 mm | 414.9 mm | 307.9 mm | 133.4 mm |

[1] summer = mean of June, July, and August data; 2 winter = mean of December, January, and February data.

# Ecological Patterns and Processes

## Ecological Zones

Coastal sand ecosystems in BC can be separated into three zones that are useful for describing and understanding ecological patterns and processes (see Figure 8): (1) sparsely-vegetated lower beach zone defined by the lower limit of terrestrial plants; (2) upper beach zone with perennial grass and forb communities; and (3) sparsely-vegetated dune zone. Many sand beaches and spits have only lower and upper beach zones, and the development of dunes is relatively rare in BC.

In the lower beach zone, plant diversity is low because of the combined effects of frequent disturbance from waves and tides and high physical stress caused by high soil salinity and low nutrient availability (Ranwell, 1972; Barbour and De Jong, 1977; Hesp, 1989; Gagne and Houle, 2002). Species richness increases as these effects diminish with increasing distance inland. The effects of marine processes (e.g., waves, tides, ocean spray) on plant establishment and growth are most intense within a narrow band near the shoreline and decline rapidly inland (Houle, 1997; Wilson and Sykes, 1999; Verhoeven, 2002). Invasive plant species are also infrequent in the lower beach zone, although the introduced searockets *(Cakile edentula* and *C. maritima)* (Boyd and Barbour, 1986; Davy *et al*., 2006) are characteristic plants of the lower beach zone throughout the BC coast. Few species at risk have been recorded from the lower beach zone although pink sand-verbena is an important exception. Silky beach pea *(Lathyrus littoralis)* is occasionally found in lower beach habitats but populations are usually short-lived (N. Page, pers. obs.). Invertebrates such as tiger beetles and isopods forage in this zone and more surveys may identify more rare invertebrate species. Ecological communities found in the lower beach zone include American searocket *(Cakile edentula)* Sparse Vegetation and occasionally large-headed sedge *(Carex macrocephala)* Herbaceous Vegetation (a red-listed community in BC). On Haida Gwaii, sea bluebells *(Mertensia maritima)* and beach groundsel *(Senecio pseudoarnica)* grow in the lower beach zone, often as isolated plants in front of the other vegetation (B. Wijdeven, pers. obs.).

The upper beach zone supports a grass-dominated community along the BC coast, typically characterized by dune wildrye and perennial forbs such as beach pea. This zone generally corresponds to the development of a foredune ridge or storm berm as well as the peak in soil fertility, with more total carbon and total nitrogen than is found in the lower beach or dune zones. Increased soil carbon and nitrogen on the beach ridge is likely caused by the conversion and internal cycling of inorganic soil nutrients into organic constituents by plant growth and decomposition (Tamm, 1991; Gerlach *et al*., 1994). Marine-derived nutrients from salt spray and organic detritus moved by large storms may also be important. The internal feedback between biotic and abiotic processes leads to nutrient enrichment and, ultimately, increased plant species richness and growth. Other factors, such as the role of mycorrhizal fungi in releasing nutrients that are associated with sand grains, may also be important in increasing the rate of nutrient enrichment in the upper beach zone (Jehne and Thompson, 1981; Cain *et al*., 1999). Similarly, the increase in organic matter in the beach ridge may improve water holding capacity compared to the lower beach or dunes. There are few species at risk confined to the upper beach zone although it does support rare noctuid moths such as Edwards' Beach Moth *(Anarta edwardsii)*. Ecological communities in the upper beach include dune wildrye grass — coastal strawberry *(Leymus mollis — Fragaria chiloensis)* Herbaceous Vegetation, dune wildrye — beach pea *(Leymus mollis* spp. *mollis — Lathyrus japonicus)* Herbaceous Vegetation (red-listed), European beachgrass *(Ammophila arenaria)* Herbaceous Vegetation, and occasionally large-headed sedge *(Carex macrocephala)* Herbaceous Vegetation.

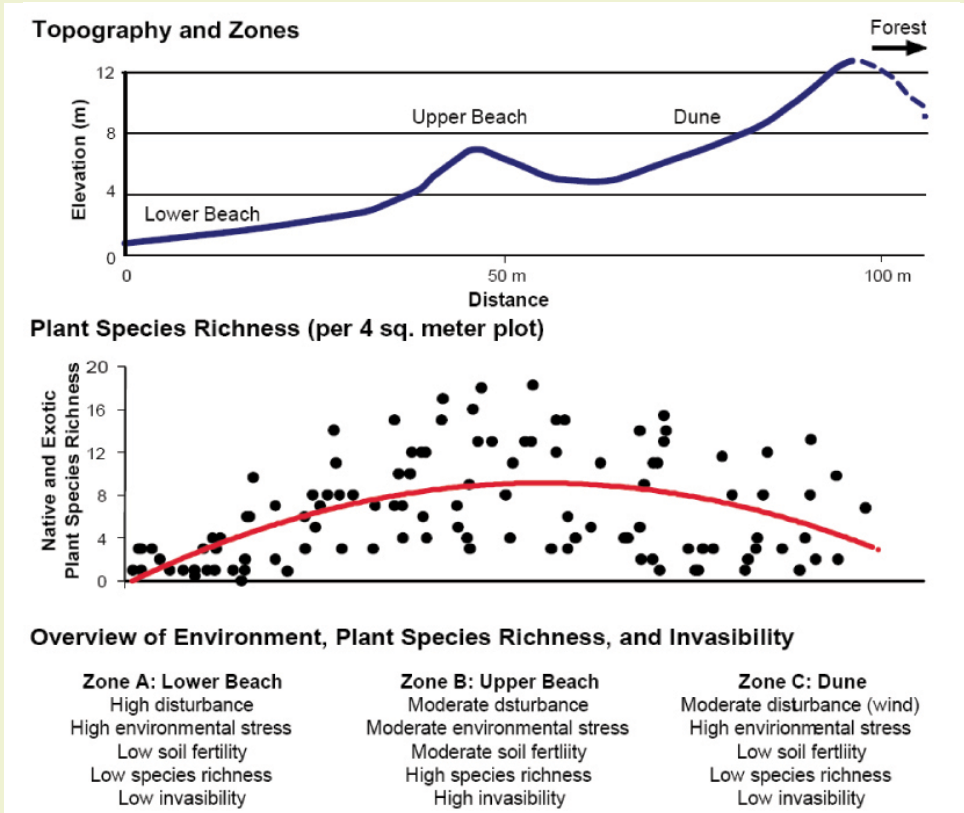



**FIGURE 8.** SCHEMATIC DEPICTION OF ECOLOGICAL ZONES IN COASTAL SAND ECOSYSTEMS IN BC. Patterns of topography, environmental conditions, plant species richness, and invasibility are distinct between the lower beach, upper beach, and dune zones. Data shown in the lower graph are from 110 vegetation plots (4 sq. meter) surveyed in six beaches on the west coast of Vancouver Island (Page, 2003). They are from selected transects measured perpendicular to the shore beginning at the seaward extent of annual or perennial vegetation.

Dunes occur relatively infrequently in coastal sand ecosystems in BC because of limited sand supply. Plant species richness and plant cover generally decline landward of the upper beach. However, it is unclear if low species richness and low total foliar cover in the dune zone is caused primarily by nutrient decline, related soil fertility changes accompanying soil development, or other factors such as wind disturbance or low soil moisture. Nutrients in sandy soils are impoverished by long-term soil development processes (Salisbury, 1925; Walker *et al*., 1981; Sevink, 1991; Verhoeven, 2002). Over time, calcium carbonate, nitrate, and organic constituents are lost from surface horizons because of precipitation-induced soil weathering and leaching (Salisbury, 1925; Walker *et al*., 1981; Kellman and Roulet, 1990). Walker *et al*. (1981) referred to this as “nutrient leakage” and documented phosphorous and calcium enrichment of lower soil horizons in Australian dune soils as surface concentrations declined. The high annual precipitation on the west coast of Vancouver Island (>2500 mm/annually) likely accelerates leaching. Dunes have relatively few species but they often contain more species of conservation significance. In BC, a disproportionate number of rare plants are found in dunes, and more surveys of ground-based arthropods, bryophytes, lichens, and others will likely identify additional rare species. Two ecological communities at risk in BC, Pacific wormwood — red fescue — Racomitrium moss Herbaceous Vegetation and Dune bluegrass Sparse Vegetation, occur predominantly in dunes in the Georgia Basin and the west coast of Vancouver Island, respectively. Kinnikinnick Dwarf Shrubland Vegetation also occurs on the margin of dunes on the west coast of Vancouver Island.

## Natural and Accelerated Succession

Most of the plant and animal species at risk in coastal sand ecosystems are associated with sparsely-vegetated communities and the primary threat is the development of more stable and densely vegetated communities through accelerated succession. While succession[4] is a natural process in coastal sand ecosystems and results in assemblage of younger and older communities on most sites, there is evidence that the rate of succession has accelerated in some coastal sand ecosystems in BC. This process has also been observed in sand ecosystems in western Europe where it may be a response to atmospheric nitrogen deposition (Jones *et al*., 2004). In BC, invasive plants, reduced sand supply, and atmospheric nitrogen deposition (see Threats section) may contribute to accelerated succession.

In coastal sand ecosystems in BC, succession from sparsely-vegetated communities is often initiated by pioneering bryophytes (e.g., *Racomitrium canescens, Dicranum* spp., *Tortula ruralis,* etc.) which facilitate the establishment of perennial grasses, forbs, and some shrubs (Figures 9 and 11). Bryophytes are able to colonize open sand if sand movement by wind is relatively minimal. Bryophyte mats provide sites for forb, shrub, and tree seedlings to establish by reducing summer moisture stress in sandy soils and protecting limited organic matter from leaching (Parker, 2002). Biological nitrogen fixation from bryophytes may also be an important process in succession; Jones *et al*. (2008) found that biological fixation by lichens and other bryophytes can contribute 10–60 kgN/ha/yr to coastal sand ecosystems. Parker (2001) found cryptogamic crusts (also dominated by *Racomitrium* mosses) facilitated Scotch broom establishment in glacial outwash prairies in central WA, a similar environment to coastal sand ecosystems, by providing “safe sites” for seedling germination and growth. Scotch broom invasion in Georgia Basin sites such as Goose and Witty’s spits also appears to be supported by bryophyte crusts, particularly by reducing moisture stress during the first growing season (N. Page, pers. obs.). Where the bryophyte mat was removed at Goose Spit as part of restoration activities, broom seedlings germinated but often failed to survive drought conditions in late summer. Kinnikinnick on the margin of dunes in west coast Vancouver Island sites may also promote the establishment of forest species, particularly salal *(Gaultheria shallon)*, western hemlock *(Tsuga heterophylla)*, and western redcedar *(Thuja plicata)*, by increasing organic matter and reducing moisture stress.

Sparsely-vegetated communities are prevalent in coastal sand ecosystems because dry, nutrient-poor soils are difficult for many plants to colonize, in combination with the movement of sand by wind and coastal processes which limits the development of stabilizing vegetation. These attributes can be modified by anthropogenic factors resulting in accelerated succession. Potential factors affecting coastal sand ecosystems in BC include:

- Reduced sand movement to backshore and dune habitats caused by reduced sediment supply, impeded coastal sediment transport, or disruption of sand movement from the beachface from log debris may enhance vegetation establishment by increasing surface stability;
- Non-native plant species such as European beachgrass may reduce sand movement and promote the establishment of other plants including byrophytes; and
- Increased nutrient-availability from atmospheric deposition or the presence of nitrogen-fixing plants such as tree lupine *(Lupinus arboreus)* may increase soil fertility and increase bryophyte or vascular plant establishment and growth.

4 Succession is the orderly change in the composition and structure of an ecological community over time caused by the replacement of species in response to environmental and climate factors.

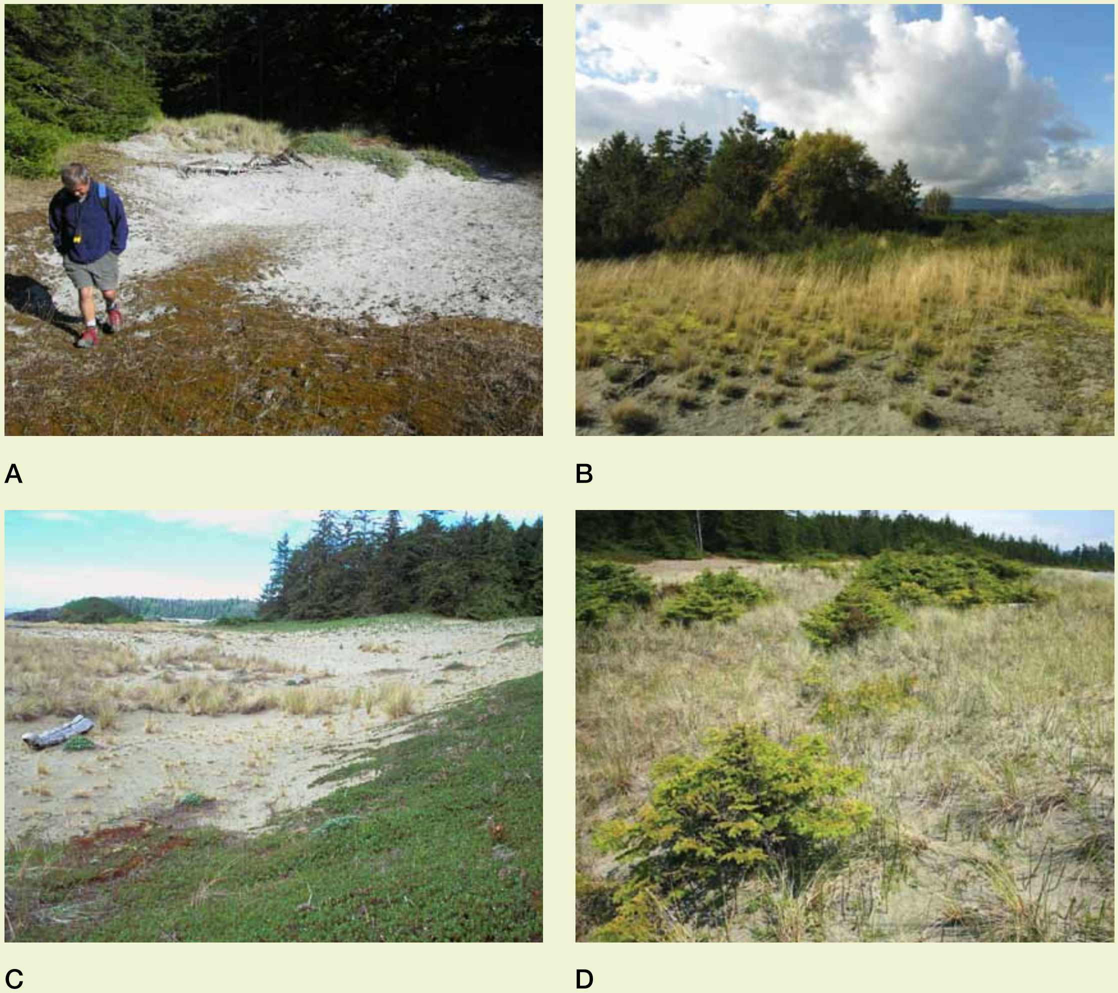


FIGURE 9. EXAMPLES OF VEGETATION SUCCESSION IN COASTAL SAND ECOSYSTEMS IN BC: a) bryophyte mat forming on a small dune blowout on the west coast of Nootka Island. Note, hummocks stabilized by silvery burweed and European beachgrass in background; b) red fescue and *Racomitrium* colonizing open dunes at a Georgia Basin site. Young Douglas-fir and big-leaf maple forest is present in the background, and dense Scotch broom shrub thickets are visible on the right; c) kinnikinnick colonizing the dune margin at Schooner Cove; and d) Sitka spruce saplings growing on an *Ammophila* dominated foredune ridge at Schooner Cove. Photos by N. Page.

In general, the relative importance of these processes is poorly understood and more work is needed to better understand which factors affect successional rates. It also is important to note that longer-term geologic or seismic processes such as tsunamis may also contribute to successional trends on sites on the west coast of Vancouver Island. Tsunamis may cause infrequent but intense disturbance to existing coastal sand ecosystems, or initiate new sites by removing existing vegetation. Because many sites are affected at the same time, successional trends may be synchronized.

# Species and Ecological Communities at Risk

This section summarizes information on species and ecological communities at risk in coastal sand ecosystems. Five groups are discussed: (1) vascular plants; (2) bryophytes, lichens, and fungi; (3) vertebrates; (4) invertebrates; and (5) ecological communities. For some groups, we also provide information on more common species that are characteristic of these ecosystems.

Information was obtained from published information, student theses, government or consultant reports, government databases, web sources, and personal communications with knowledgeable biologists and naturalists (Appendix 2). Because of the relatively poor level of knowledge about some groups or taxa, species that may be rare but are poorly known are included. Taxonomic uncertainties are noted where they may affect conservation assessments. Information gaps and research priorities are also noted for each group.

## Vascular Plants

Coastal sand ecosystems support a range of vascular plant species[5] which are rare at a national, provincial, or regional scale. Some can be considered obligate species which are found only in coastal sand ecosystems, while others are found in a broader range of open habitats such as coastal meadows and rock bluffs. Grasses, annual forbs, and long-lived perennials are the best represented of the plant groups, and reflect different strategies for coping with the stressful environmental conditions in coastal sand ecosystems. For example, contorted-pod evening-primrose is an annual species that grows and reproduces before the driest part of the year, while yellow sand-verbena *(Abronia latifolia)* and American glehnia *(Glehnia littoralis* ssp. *leiocarpa)* are long-lived perennials with large under-ground roots and low, sprawling growth.

***Existing Information***. The following information sources were used to compile and identify vascular plants of conservation significance in coastal sand ecosystems:

- BC Conservation Data Centre (BC CDC) database tracks and assigns conservation ranks to all vascular plant species in BC (BC CDC, 2010);
- University of British Columbia and Royal British Columbia Museum herbaria maintain the most extensive collection of plant records for BC;
- Theses, consultant reports, or informal plant surveys are available such as Page (2003), Kuramoto (1965); Hamel and Hearne (2004);
- Ecological studies on plant communities including: Kuramoto (1965); Page (2003); Roemer (2000, 2001); and Hebda *et al*. (1997);
- Rare Vascular Plants of BC by Straley *et al*. (1996); and
- Personal communications from local botanists including Adolf Ceska, Matt Fairbarns, and Frank Lomer.

5 The term Vascular plants include trees, shrubs, grasses, sedges, ferns, and flowering plants. It does not include bryophytes.

A

B

C

D

E

F

**FIGURE 10.** EXAMPLES OF VASCULAR PLANTS AND FUNGI OF CONSERVATION SIGNIFICANCE IN COASTAL SAND ECOSYSTEMS: a) contorted-pod evening-primrose (Savary Island); b) pink sand-verbena (Clo-oose Bay, West Coast Trail, BC); c) silky beach pea (Wickaninnish Beach); d) non-pinnate subspecies of silver burweed (Schooner Cove); e) *Agrocybe pediades* (unranked) (Rose Spit, Haida Gwaii); and f) *Cordyceps ravelenii* (unranked) (Schooner Cove). Photo a by I. Cumming, b by R. Vennesland, c and d by N. Page, e and f by A. Ceska.

***Species of Conservation Significance.*** Twenty-five vascular plant taxa of potential conservation significance were identified in coastal sand ecosystems. They include two species currently on Schedule 1 of the *Species at Risk Act* (SARA) (pink sand-verbena *(Abronia umbellata)* and contorted-pod evening-primrose *(Camissonia contorta)*), and twenty species ranked S2 (imperiled) to S3S4 (vulnerable/apparently secure) or higher by the BC Conservation Data Centre. Three potentially rare taxa that require additional assessment to determine their conservation significance were also included: *Leymus* hybrids that are poorly described; the non-pinnate form of silver burweed; and the subspecies of northern wormwood that is taxonomically uncertain. The following list should be considered preliminary; the order is based on current BC CDC ranks.

**Pink sand-verbena** *(Abronia umbellata* ssp. *brevifolia)*: annual or biannual species found on exposed sand beaches on the west coast of Vancouver Island; the subspecies *breviflora*, the only one to occur in Canada, is restricted to shorelines from Vancouver Island to the central coast of California; in BC, restricted to lower and upper beach communities with a substrate of fine sand, but also occurs in dune habitats in Oregon and California; designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (2004); considered one of the rarest plants in Canada (Douglas, 2001); globally threatened and the U.S. Fish and Wildlife Service has identified it as a Species of Concern; small population assisted by recovery actions in Pacific Rim National Park Reserve; conservation status: G4G5TNR, S1, Endangered); see Parks Canada, 2008; Douglas, 2004; Fairbarns *et al*., 2007; Fairbarns, 2008; Tillett, 1967; see photo in Figure 10.

**Contorted-pod evening-primrose** *(Camissonia contorta)*: diminutive annual plant found in open sand; designated as Endangered by COSEWIC; confined to southern Strait of Georgia sites (8 extant populations and one extirpated population in Canada); small fragmented distribution; conservation status: G5, S1, Endangered); see status report and recovery strategy (COSEWIC, 2006; Fairbarns and Vennesland, in prep.; Parks Canada, 2009); see photo in Figure 10.

**Sandmat** *(Cardionema ramosissimum)*: clumping mat-forming perennial plant which grows along beaches of western North America; very rare in BC; found in sandy-gravel substrate at Muir Creek west of Sooke; conservation status: G5?, S1, Red.

**Fern-leaved desert-parsely** *(Lomatium dissectum* var. *dissectum)*: a member of the carrot family found rarely in dry meadows and rock bluffs in the southern Georgia Basin; it may occur with barestem desert-parsley in some coastal sand ecosystems; conservation status: G4T4, S1, Red, COSEWIC status report under development.

**Silky beach pea (grey beach peavine)** *(Lathyrus littoralis)*: distinctive glaucus, hairy pea found in dunes and some sand beaches; largest populations at Wickaninnish Beach and in Naikoon Provincial Park; considered very rare and a candidate species for SARA listing; nine populations known at present in BC; conservation status: G5, S2, Red, COSEWIC status report under development; see Figure 10.

**Sand dune sedge** *(Carex pansa)*: perennial sedge occasionally found in sand but more often in shell-gravel deposits on rock shorelines on the west coast Vancouver Island; several botanists have remarked that the common name is inappropriate, at least for BC populations; conservation status: G4, S2S3, Blue.

**Beach groundsel** *(Senecio pseudoarnica)*: found in sandy and gravelly beaches of northern coast of Graham Island (Haida Gwaii); not strictly associated with sand ecosystems; conservation status: G5, S2S3, Blue.

**Sea bluebells** *(Mertensia maritima)*: perennial herb found in sand and gravel beaches of Haida Gwaii; conservation status: G5, S2S3, Blue.

**Kamchatka spike-rush** *(Eleocharis kamtschatica)*: spike-rush more commonly found in wetlands of the north coast; reported from sand dunes on Haida Gwaii; conservation status: G4, S2S3, Blue.

**Beach bindweed** (beach morning glory) *(Convolvulus soldanella* syn. *Calystegia soldanella)*: sprawling, long-lived perennial found on sand beaches and dunes; locally abundant where it occurs; conservation status: G5, S3, Blue.

**American glehnia** *(Glehnia littoralis* ssp. *leiocarpa)*: long-lived perennial carrot characteristic of dunes and some upper beaches; more common on west coast of Vancouver Island but rare in Georgia Basin (very small populations observed at Sidney Spit and Cordova Spit); conservation status: G5T5, S3, Blue.

**California wax-myrtle** *(Myrica californica)*: waxy-leaved shrub on forest margin and dune edges in Clayoquot Sound and Pacific Rim National Park Reserve; disjunct population from main population centre in Oregon and California; conservation status: G5, S3, Blue.

**Black knotweed** *(Polygonum paronychia)*: long-lived low shrub that is a characteristic species in dunes both in Georgia Basin and west coast; sometimes found in more terrestrial environments; conservation status: G5, S3, Blue.

**Dune bentgrass** *(Agrostis pallens)*: perennial grass found in sand beaches and dunes; conservation status: G4G5, S3, Yellow.

**Beach bluegrass** *(Poa confinis)*: perennial grass found on semi-stable sand dunes and beaches throughout coastal BC; uncommon on the west coast of Vancouver Island; conservation status: G5, S3S4, Yellow.

**Vancouver wildrye** *(Leymus x vancouverensis* hybrid): a hybrid of *Leymus mollis* and an unknown species, possibly *Leymus triticoides*; rhizomatous and locally abundant in sand dunes, spits, and beaches in the Georgia Basin; this taxa has replaced older collections of *Leymus triticoides* in coastal BC and Flora of North America treatment has addressed taxonomic uncertainties (Bowden, 1957, 1959); conservation status: GNA, S3S4, Yellow.

**Large-headed sedge** *(Carex macrocephala)*: distinctive sedge that forms large mono typic patches in dunes and upper beaches; sometimes present on gravelly beaches; often locally abundant in suitable habitat and forms a distinct ecological community; conservation status: G5, S3S4, Yellow.

**Dune bluegrass** *(Poa macrantha)*: clump forming perennial grass that spreads from rhizomes; often the dominant plant on sand dunes of the west coast of Vancouver Island and Haida Gwaii; sometimes on the upper margin of beaches; rare in the Georgia Basin; conservation status: G5, S3S4, Yellow.

**Gold star** *(Crocidium multicaule)*: small annual sunflower that is locally abundant in some dunes such as Goose Spit; flowers in early spring; also found on bluffs and other coastal sites; conservation status: G5, S3S4, Yellow.

**Seashore lupine** *(Lupinus littoralis)*: perennial lupine found sporadically in dunes and upper beaches; some populations may be hybrids; conservation status: G5, S3S4, Yellow.

**Dune tansy** *(Tanacetum bipinnatum* ssp. *huronense)*: occurs along the margin of sand, gravel, and shell beaches or dunes on the west coast of Vancouver Island and Haida Gwaii; often patchy in distribution with small localized populations; conservation status: G5T4T5, S3S4, Yellow.

**Seaside fiddleneck** *(Amsinckia spectabilis)*: Annual herb from a taproot; occurs in upper beach areas above the driftline in sand ecosystems of the Georgia Basin and Haida Gwaii; not reported from the west coast of Vancouver Island; conservation status: G4G5, S3S4, Yellow.

**Brewer's rush** *(Juncus breweri)*: rhizomatous rush found in dunes or find sand areas with seepage; conservation status: G3, S3S4, Yellow.

**Silver burweed** *(Ambrosia chamissonis)*: long-lived perennial common in sandy and gravelly beaches in BC; the non-bipinnate taxa is rare (found mainly at Schooner Cove dune and occasionally at Wickanninish Beach; see Figure 10) and may be of conservation significance, although leaf-shape may intergrade on Pacific Coast (Hickman, 1993); conservation status: subspecies or varieties are unranked at this time.

**Northern wormwood** *(Artemisia campestris* ssp. *pacifica)*: taxonomically confusing wormwood species sometimes found in sand dunes in the Georgia Basin (see Figure 11); subspecies needs review; conservation status: G5T5, S5, Yellow.

**Leymus Hybrids** *(Leymus x* taxa): poorly understood group of hybrid grasses between *Leymus mollis* and *Elymus* species or other taxa; Flora of BC notes: "a hybrid between *Leymus mollis* and *Elymus glaucus*, known only from Ucluelet and Gold River, has been named *Leymus x uclueletensis* (Bowden) Baum (Elymus x uclueletensis Bowden)"; see Bowden (1957, 1959) and Hitchcock *et al*. (1969); other hybrids may occur on sand beaches on the west coast of Vancouver Island (N. Page, pers. obs.) and more taxonomic and/or genetic work is needed.

### *Knowledge Gaps and Research Priorities for Vascular Plants*

1. Undertake additional surveys for silky beach pea;
2. Review taxonomic uncertainties and conservation ranks for silver burweed (nonbipinnate form), northern wormwood, dune bluegrass, Vancouver wildrye, and *Leymus* hybrids; and
3. Review conservation rank for sand dune sedge.

## Bryophytes, Lichens, and Fungi

### BRYOPHYTES

Bryophytes (mosses, liverworts) play a significant role in stabilization, moisture retention, habitat succession, and nutrient cycling in coastal sand ecosystems. Because bryophytes are less tolerant of rapid sand accumulation (Maun, 1998), they tend to colonize older dune and spit areas where vascular plants have provided some initial stabilization and sand deposition has largely ceased (Robbins, 1952) Figure 11. Bryophytes further stabilize the dunes and help to retain soil moisture. On foredunes and sand beaches, salt spray (or periodic inundation) limits the distribution of bryophytes in the upper intertidal zone as few bryophyte species have evolved salt tolerance (Boerner and Forman, 1975). Because dune soils are very well-drained, most bryophytes inhabiting coastal sand sites are drought-tolerant species.

On stabilized sites, bryophyte communities facilitate the initial development of a surface humus layer, which precedes enrichment of lower soil layers. If natural disturbances do not destabilize the dune, forest succession will take place over time. Many bryophytes are sensitive to high levels of disturbance from coastal development, changes in grazing regime, shrub encroachment, drainage alterations, or nutrient enrichment.

A B

**FIGURE 11.** BRYOPHYTE DEVELOPMENT IN COASTAL SAND ECOSYSTEMS: a) bryophyte and lichen-rich dune hummocks developed around silver burweed plants (Schooner Cove dune, Pacific Rim National Park Reserve; b) bryophyte stabilized dune ridge in Sandy Island Provincial Park with red fescue and northern wormwood. Photos by N. Page.

***Existing Information.*** Bryophyte communities on sand dunes and beaches in coastal BC are not well-studied and few inventories have been conducted. An incomplete survey of moss and liverwort species on Savary Island was conducted in 2000 (Sadler, 2000). One blue-listed moss species, *Homalothecium arenarium*, was located in the dunes. Some rare bryophyte species found in open, sparsely vegetated, partially sandy or rocky sites with may also be associated in coastal sand habitats. Other rare species are likely yet to be discovered.

***Species of Potential Conservation Concern.*** The following bryophytes are species of potential conservation concern in BC. The list was assembled using available information sources and consultation of several bryophyte experts (see Appendix 2):

### MOSSES

**Rare Mosses:** *Bryum violaceum* (G5?, S1, Red), *Bryum capillare* var. *torquescens* (G5TNR, S2S3, Blue), *Bryum canariense* (G3G5, S2, Blue), *Didymodon vinealis* var. *nicholsonii* (G5TNR, S1, Red) , *Epipterygium tozeri* (G4?, S2S3, Blue), *Tortula papillosissima* (G3G5, S2S3, Blue): group of rare mosses found in open, undeveloped habitats, some in sandy areas where sand is mixed with a bit of soil and in shallow soils overlying rock (K. Sadler, pers. comm.).

***Homalothecium arenarium:*** known from dunes on Savary Island (Sadler, 2000); conservation status: G4, S2S3, Blue.

**Frye's swamp moss** (Frye's limbella moss) *(Limbella fryei)*: endemic to the Pacific Northwest, this obligate wetland species is known from shrub-swamps behind dunes in southern Oregon (Natureserve 2009); unlikely but possibly found in BC (J. Harpel, pers. comm.); conservation status: G1 (species of concern in US).

### LIVERWORTS

No rare liverworts associated with coastal sand ecosystems are currently known.

### LICHENS

Lichen diversity in coastal sand ecosystems includes soil-dwelling species as well as species epiphytic on other vegetation, particularly shrubs, trees, and downed wood. Soil-dwelling lichens can contribute to stabilization and moisture retention. Epiphytic lichens are important food for ungulate species and other mammals, provide nesting material for birds, and habitat for smaller organisms, such as insects, invertebrates, and microbiota (Goward *et al*., 1995). High lichen diversity is often associated with the older dune forests which have colonized stabilized dunes behind active dunes on the exposed, outer west coast (Glavich *et al*., 2005). Lichens inhabiting the dunes themselves must be tolerant to the frequent drying associated with exposed, well-drained sandy habitats.

***Existing Information.*** Like bryophytes, few inventories of lichens on sand dunes and beaches in coastal BC have been undertaken. A potentially rare undescribed lichen species (member of the *Peltigera aphthosa* group) has been collected from the dunes at Pacific Rim National Park Reserve (T. Goward, pers. comm.). Several rare lichens are known from "dune forests" that have developed over top of and behind dunes on the west coast of North America (Glavich *et al*., 2005). Some of these species have been found in BC (Goward, 1995), while others are currently known from similar habitats in Washington and Oregon and could be present here.

***Species of Potential Conservation Concern.*** The following annotated list describes lichen species of potential conservation concern in BC. The list was assembled using available information sources and consultation of several lichen experts:

**Undescribed member of the *Peltigera aphthosa* Group:** collected from the dunes at Pacific Rim National Park Reserve, but could be a strange morph of *Peltigera leucophlebia* (T. Goward, pers. comm.).

***Cladonia concinna*** (Ahti & Goward): newly described species from dry, rocky powerline area through Douglas-fir forest on Vancouver Island; may occur in coastal sand ecosystems (T. Spribille, pers. comm.).

**Rare Lichens of Oregon Dunes:** *(Bryoria pseudocapillaris, B. spiralifera, B. subcana, Erioderma sorediatum, Heterodermia leucomela, Hypotrachyna revoluta, Leioderma sorediatum, Leptogium brebissonii, Niebla cephalota, Pannaria rubiginosa, Pseudocyphellaria perpetua, Pyrrhospora quernea, Ramalina pollinaria, Teloschistes flavicans, and Usnea hesperina)*: rare lichens known from the coastal U.S. Pacific Northwest, particularly Oregon Dunes. Most appear to be associated with coastal rainforests, some of which are adjacent to dunes (Glavich *et al*., 2005). At least two of these species *(Leptogium brebissionii, Pannaria rubiginosa)* are also known from coastal BC (Goward *et al*., 1994, Goward, 1995). Kaye *et al*. (1997) noted that: “the dune sheet from Heceta Head to Coos Bay contains a rich lichen flora with many rare species, including most or all of the Oregon locations of *Bryoria furcellata, B. pseudocapillaris, Erioderma sorediatum, Heterodermia sp.,* and *Leioderma sorediatum*. In addition this area hosts notable populations of *Pannaria rubiginos* and *Usnea hesperina*. Two kinds of sand dune vegetation seem to hold the most species: old, open conifer stands with broken ericaceous understory and wetlands with large old shrubs. The dunes deserve much more exploration so that we can better set conservation priorities and more conifidently distinguish between true rarity and sparseness of field work.”

## FUNGI

Fungi perform an essential role in all ecosystems in decomposing organic matter and in nutrient cycling and exchange. In coastal sand ecosystems, the initial establishment, growth, and survival of most vascular plants is thought to depend on symbiosis with mycorrhizal fungi (Koske *et al*., 2004). Fungal mycelia provide mineral nutrients in exchange for carbon compounds of the host plant (Smith and Read, 1997). Arbuscular fungi (AM) form associations with the roots of plants and facilitate establishment of many native dune species but also invasive species, thereby having a role in dune stabilization. Studies have demonstrated the dependence of European beachgrass on the establishment of mycorrhizal relationships in dune soils (Koske and Polson, 1984). Ectomychorrizal fungi (EMF) also contribute to tree and shrub establishment and primary forest succession on coastal dunes (Ashkannejhad and Horton, 2005). In contrast, some fungi can be pathogenic to dune plants and provide an indirect mechanism for plant species competition and succession (Van Der Putten and Peters, 1997). Mycorrhizae are known to improve soil structure and stability by forming aggregates. They can also have important relationships with vertebrates (e.g., deer dispersed spores) and invertebrates (specialized food and habitats) (Ashkannejhad and Horton, 2005).

***Existing Information.*** Information on fungal species distribution and roles in coastal sand ecosystems is limited in coastal BC, although their ecological importance here are likely no less important than has been found in studies elsewhere. Macrofungi surveys were conducted at three dune sites (Wickaninnish, Schooner Cove, Ahous Bay (Vargas Island)) as part of extensive surveys of the Clayoquot Sound area from 1998–2001 (Roberts *et al*., 2004). Initial surveys have also been undertaken on Rose Spit and in Tlell (B. Wijdeven, pers. comm.).

***Species of Potential Conservation Concern.*** The following annotated list describes fungi species of potential conservation concern in BC. The list was assembled using the available information sources mentioned above and consultation of several fungi experts (Appendix 2).

***Cantharellus cibarius* Fr. var. *roseocanus*** Redhead, Norvell & Danell: a recently discovered chanterelle closely related to the European chanterelle; found in forested pockets of dunes of Clayoquot Sound (Roberts *et al*., 2004).

***Cordyceps ravenelii*** Berkeley & Curtis: a rare fungus that parasitizes the larvae of Ten-lined June Beetle *(Polyphylla decemlineata)* pupating underground amongst dune grasses; first BC record was from Vargas Island dunes in 2001 (N. Page pers. obs.); also recorded in dunes at Schooner Cove and on San Juan Island (A. Ceska, pers. comm.); searched for but not found in the Wickaninnish dunes (Roberts *et al*., 2004). The taxonomy of this species is still under review.

***Hygrophorus inocybiformis*** Smith: found in forested pockets of dunes of Clayoquot Sound; collected only once previously in northwestern California (Roberts *et al*., 2004).

***Tricholoma apium*** Schaeffer: recorded only from three or four sites in BC, one of which is the Wickaninnish dunes (Roberts *et al*., 2004).

### *Knowledge Gaps and Research Priorities for Bryophytes, Lichens, and Fungi*

1. Further inventories for bryophytes of coastal sand ecosystems;
2. Detailed information on habitat and plant community relationships;
3. Impacts and role of natural and anthropogenic disturbance on bryophyte communities;
4. Further inventories for lichens of coastal sand ecosystem sites; and
5. Detailed information on distribution and habitat associations.

## Vertebrates

### BIRDS

Although many resident and migratory bird species use coastal sand ecosystems, only a small number of species are more specialized on this habitat type. Historically, several rare ground-nesting species have used the sparse vegetation and soft substrate in sand dunes and spits for breeding habitat. Streaked Horned Lark *(Eremophila alpestris strigata)* is a rare subspecies of the Horned Lark that breeds in large coastal sand ecosystems in Oregon and Washington, as well as short-grass grasslands. It is a specialist of sparsely-vegetated habitats, and occurred historically in both dunes and grasslands in southwestern BC. This species is not currently known to occur in Canada and is listed as Endangered under Schedule 1 of SARA (Environment Canada, 2008). Coastal Vesper Sparrow *(Pooecetes gramineus affinis)* (Endangered under Schedule 1) and Western Meadowlark *(Sturnella neglecta confluent)* (Georgia Depression population, Extirpated) are ground-nesting open grassland species that were thought to be associated with Garry oak ecosystems in the Georgia Basin (Fuchs, 2001). However, there is evidence that one or both species may have nested in coastal sand ecosystems historically. These sparsely-vegetated habitats are also potential recovery habitat for these species. Common Nighthawk *(Chordeiles minor)* originally nested on open ground along rivers or other gravelly stretches. It has nested in dunes at Boundary Bay (G. Ryder, pers. comm.). Other more common species, such as Spotted Sandpiper *(Actitis macularius)* and Killdeer *(Charadrius vociferus)*, also nest in sparsely-vegetated sand habitats but are not restricted to coastal sand habitats. More broadly, the upper portions of sand beaches provide foraging habitat for migrating neotropical songbirds, stopover habitat for shorebirds moving on the Pacific Flyway (as part of the larger intertidal or shore zone) such as Whimbrel *(Numenius phaeopus)*, resting habitat for waterfowl such as Brant *(Branta bernicla),* and hunting territories for some raptor species.

***Existing Information.*** Numerous confirmed historical breeding records exist for Streaked Horned Lark and Coastal Vesper Sparrow in open, sparsely vegetated habitats in coastal BC (Campbell *et al*., 2001). Most biological and habitat information on these species comes from either non-sand habitat types or populations outside of Canada. Extensive monitoring and habitat assessment has been carried out on Streaked Horned Lark populations in Washington State, including several coastal dune and beach breeding sites (Pearson, 2003; Pearson and Altman, 2005; Pearson *et al*., 2005). Beauchesne (e.g., 2006) has monitored the single population of Coastal Vesper Sparrow at the Nanaimo Regional Airport since 2002. COSEWIC status reports and SARA recovery strategies for these species provide good summaries of available information. Common Nighthawk was assessed by COSEWIC in 2007 and designated as Threatened (COSEWIC, 2007). Little is known about Western Meadowlark Georgia Depression population although it is thought that breeding within the Georgia Basin is limited by disturbance and the availability of adequate nest sites as a result of human settlement (Beauchesne *et al*., 2002). No research has addressed broad bird use of coastal sand ecosystems in BC or the importance of coastal sand sites relative to other habitats used. Shorebird distribution on sandy beaches in response to beach characteristics and use is well-documented in California (e.g., Neuman *et al*., 2008). Bartley (2008) monitored migratory bird use at Cordova Spit during spring and late-summer migration periods.

***Potential Species of Conservation Concern.*** For the purposes of this report, we have defined coastal sand ecosystems to be the terrestrial and high intertidal zones of beaches, spits, and dunes in which sand is the dominant substrate. Consequently, we have divided bird species using coastal sand ecosystems into the following four categories: (1) species which breed in or spend a specific portion of the their life cycle in coastal sand ecosystems (e.g., overwintering); (3) terrestrial species which may use coastal sand sites during migration; (2) species (primarily shorebirds and waders) which may use coastal sand habitats as part of the larger intertidal/shore zone; and (4) terrestrial species which may use coastal sand sites but do not necessarily prefer these sites.

The following annotated list describes bird species associated with coastal sand ecosystems that are of potential conservation concern in BC within the above categories:

### **GROUP 1.** Coastal Sand Ecosystem Associated Birds

Species which breed in or spend a specific portion of their life cycle in coastal sand ecosystems:

**Streaked Horned Lark** *(Eremophila alpestris strigata)*: not currently known to occur or breed within historical range in Canada. Historical bred in both dune and grassland habitats, with breeding records concentrated in the Fraser Delta though breeding on Southeastern Vancouver Island is likely. Recorded from large coastal sand ecosystems (>10 ha in size) on the outer coast of WA. Global population is confined to small breeding populations in Washington and Oregon (Environment Canada, 2008). Conservation status: G5T2; SX; Red; listed as Endangered under SARA Schedule 1; a joint recovery strategy for Streaked Horned Lark and Coastal Vesper Sparrow is currently in draft form (Environment Canada, 2008).

**Coastal Vesper Sparrow** *(Pooecetes gramineus affinis)*: partial migrants which breed from southwestern BC to northern California; nests in sparsely-vegetated grassland sites with some shrubs for perching; not known from coastal sand ecosystems but may have occurred there historically; single breeding population remains in Canada (Nanaimo Regional Airport) with 6–9 breeding pairs (Environment Canada, 2008). Conservation status: G5T3; S1B, Red; listed as Endangered under SARA Schedule 1 and red-listed in BC (Beauchesne, 2005); joint recovery strategy for Streaked Horned Lark and Coastal Vesper Sparrow is currently in draft form (Environment Canada, 2008).

**Western Meadowlark** *(Sturnella neglecta)* Georgia Depression population: historically a summer breeder in the Georgia Basin and year-round resident from Washington south to Mexico (Lanyon, 1994). Not yet assessed by COSEWIC and red-listed in BC. Breeding populations thought to be extirpated from Canada, though recent non-breeding observations have been made (Beauchesne *et al*., 2002). Historical breeding records exist for Cape Lazo (Comox) in 1925 (Campbell *et al*., 2001); conservation status: G5TNRQ, SXB, Red.

**Common Nighthawk** *(Chordeiles minor)*: neotropical migrant which breeds on the BC coast and throughout most of southern Canada and U.S. Recently assessed as Threatened in Canada by COSEWIC due to declining populations (COSEWIC, 2007). Nests in a wide range of open, vegetation-free habitats, including dunes, beaches, recently harvested forests, rocky outcrops, and grasslands (COSEWIC, 2007); nests in sand spits on James and Sidney islands; conservation status: G5, S4B, Yellow.

**Band-tailed Pigeon** *(Patagioenas fasciata)*: recently assessed as Special Concern in Canada due to steady population declines since the 1960s (COSEWIC, 2008). This species was observed feeding on kinnikinnick (*Arctostaphylos uva-ursi*) berries in a small dune at Keeha Bay in 2001 and in Wickanninish Beach dunes in 2009 (N. Page, pers. obs.); conservation status: G4, S3S4B, Blue.

**Killdeer** *(Charadrius vociferous)*: Not a dune specialist but nests in open places, such as fields, pastures, and dry uplands, as well as beaches and dunes. Golf courses and airfields, with their short grass and gravelly substrate, are also favourite habitats. Once heavily impacted by development but through protection under the North American Migratory Bird Convention has seen a return to historical numbers (Verbeek and Hendricks, 1994).

**Spotted Sandpiper** *(Actitis macularia)*: Known to breed in coastal sand sites in BC (G. Ryder, pers. comm.).

### **GROUP 2.** Migratory Birds Using Coastal Sand Ecosystems

**Lapland Longspur** *(Calcarius lapponicus)*: Migrates between overwintering areas and summer breeding grounds in Arctic tundra of Alaska and northern Canada along sand beaches on coast of BC. Currently common and widespread but some populations may be declining (Hussell and Montgomerie, 2002).

**Snow Bunting** *(Plectrophenax nivalis)*: Winters in open fields and other sites along BC coast. Currently common and not threatened (Lyon and Montgomerie, 1995).

**American Pipit** *(Anthus rubescens)*: Pacific Coast *(pacificus)* subspecies uses coastal beaches in winter and during migration. May be declining (Verbeek and Hendricks, 1994).

### **GROUP 3.** Intertidal Sand Birds

There are a diverse group of shorebirds and waterfowl that feed in sandy intertidal shorelines and may occasionally use the terrestrial portion of coastal sand ecosystems. They include: Western Sandpiper (*Calidris mauri*), Least Sandpiper *(Calidris minutilla)*, Semi-palmated Sandpiper *(Calidris pusilla)*, Dunlin *(Calidris alpine)*, Greater Yellowlegs *(Tringa melanoleuca)*, Whimbrel (*Numenius phaeopus*), Black-bellied Plover *(Pluvialis squatarola)*, Short-billed Dowitcher *(Limnodromus griseus)*, Brant (*Branta bernicla*), Great Blue Heron *(Ardea herodias)*, and Sanderling *(Calidris alba)*.

**GROUP 4.** Incidental Birds in Coastal Sand Ecosystems

Terrestrial species which may use coastal sand sites but do not necessarily prefer these sites include: Savannah Sparrow *(Passerculus sandwichensis)*, Lincoln's Sparrow *(Melospiza lincolnii)*, Northwestern Crow *(Corvus caurinus)*, Common Raven *(Corvus corax)*, and Northern Saw-whet Owl *(Aegolius acadicus)*.

## MAMMALS

Mammal use of coastal sand ecosystems often occurs as part of use of adjacent forests, fields, and intertidal areas. Due to their small size relative to other ecosystem types on the BC coast, dune and sand beach sites provide only a relatively small amount of habitat for large mammals. However, because of their position and openness, they are used as movement corridors. Large carnivores, such as Black Bear *(Ursus americanus)* and Grey Wolf *(Canis lupis)*, may use sand dunes and beaches to access intertidal areas and for moving along the coastline. Studies have found that diets of grey wolves living in coastal BC encompass a range of prey associated with the marine environment, including salmon, seal pups, and beached whales (Darimont *et al*., 2009) and that habitat structure and connectivity influences diet (Paquet *et al*., 2006). Coastal grey wolves have been found to be genetically distinct from other North American populations and may warrant protection as an Ecologically Significant Unit (Munoz-Fuentes, 2009). Large ungulates, such as Columbian Black-tailed Deer *(Odocoileus hemionus columbianus)* and Roosevelt Elk *(Cervus canadensis roosevelti)*, may impact sand plant species growth and play a role in seed dispersal. Deer have been observed browsing on yellow sand-verbena on Goose Spit when other plants have senesced (BC Invertebrates Recovery Team, 2008). The presence of introduced herbivores, such as Fallow Deer *(Dama dama)* on James and Sidney islands or Eastern Cottontail *(Sylvilagus floridanus)* on Goose Spit and other sites, may have additional impacts. Feral cattle occur occasionally in coastal sand sites in BC (Marina Island, Haida Gwaii).

No small mammals from BC are known to be specialized on dune habitats, however, North American Deer Mouse *(Peromyscus maniculatus)* and Keen's (Northwestern) Mouse *(Peromyscus keeni)* are known to be more abundant in beach habitats on coastal islands and some areas of Vancouver Island than in adjacent forests (Thomas, 1971). Bat use of coastal sand ecosystems is poorly known (D. Nagorsen, pers. comm.).

## REPTILES AND AMPHIBIANS

Coastal sand ecosystems offer suitable habitat for a small number of reptile and amphibian species, none of which are currently known to be at risk in BC:

**Western Terrestrial Garter Snake** *(Thamnophis elegans)*: uses sand dunes and beaches extensively throughout coastal BC (K. Ovaska, pers. comm.; N. Page, pers. obs.). This species feeds on invertebrate and vertebrate prey captured on both land and in water; conservation status: G5, S5.

**Northern Alligator Lizard** *(Elgaria coerulea)*: may possibly use sand dunes and spits as basking sites. A closely-related subspecies is known from dune sites in California; conservation status: G5, S4S5.

**Wandering Salamander** *(Aneides vagrans)*: typically is found under logs in low-elevation, humid coastal forests (Corkran and Thoms, 1996) but there are records of this species from under beach logs on the west coast of Vancouver Island (K. Ovaska, pers. comm.) and evidence of use of seabird nesting burrows as refuges (Cleland Island) (Campbell and Stirling, 1968); conservation status: G5, S4.

***Knowledge Gaps and Research Priorities for Vertebrates.***

1. Importance of coastal sand sites relative to other habitat types for bird use;
2. Distribution of recovery habitat for Streaked Horned Lark and/or Coastal Vesper Sparrow;
3. Effect of introduced species on habitat suitability for ground-nesting species;
4. Impacts of native herbivores on coastal sand plant species and ecological communities;
5. Impacts of non-native herbivores, particularly introduced rabbits, on coastal sand plant communities;
6. Role of mammals in coastal sand plant seed dispersal; and
7. Survey reptiles and amphibians as part of biodiversity inventories.

## Invertebrates

Coastal sand ecosystems around the world support diverse and abundant terrestrial invertebrate communities. The zonation of coastal sand ecosystems means that a variety of successional stages and habitat types can occur within a small area. Many border other unique and ecologically-rich invertebrate habitats, such as salt marshes or estuaries. Similar to the vascular plant flora, coastal sand ecosystems also have a high proportion of invertebrate species with life histories uniquely adapted for sand dune or sand beach environments and that do not occur anywhere else. They either depend on the unique environmental conditions or have a specific relationship with another sand-specific host species. Moths and beetles are two invertebrate groups with specific taxa that are adapted for sand dune and sand beach environments such as below-ground diapause. Specialized relationships likely exist for other invertebrate groups but are less well-documented and reflect the general lack of knowledge about many invertebrate taxa. Broadly, invertebrates play an important role in ecosystems by contributing to nutrient cycling and as important food sources for birds and other animals.

***Existing Information.*** Species and distribution information on invertebrate taxa inhabiting coastal sand ecosystems in BC is sparse and largely incomplete. For most species, information is limited to only a small number of occurrence records at one or a few sites. Little life history or habitat information exists for most species. Scudder (1994 and 1996) provide annotated lists of potentially rare and endangered terrestrial invertebrates from BC, some of which are known from coastal sand ecosystems. Some of the records lack detailed location or habitat information. In many cases, it is likely that sampling was carried out opportunistically and not focused specifically on sandy habitats making their associations with coastal sand ecosystems difficult to assess.

A few invertebrate surveys focused on coastal sand ecosystems in BC have been recently conducted. Troubridge and Crabo (1995) sampled noctuid moths on beaches in the Strait of Juan de Fuca and the Gulf of Georgia and found a new species, Sand-verbena Moth *(Copablepharon fuscum)*, and also that several species that occur in California and Oregon also occur in the Pacific Northwest. Nick Page sampled moths at approximately 60 locations in coastal sand sites in the Georgia Basin and on the west coast of Vancouver Island from 2001–2007 and identified several sites inhabited by Sand-verbena Moth and Edwards' Beach Moth *(Anarta edwardsii)* (COSEWIC, 2003; COSEWIC, 2009; unpublished data). These two species are probably the most studied invertebrate species inhabiting BC coastal sand sites. Pitfall trapping has been conducted on Savary Island and spider sampling has been conducted at Island View Beach by Robb Bennett (unpublished data). Troubridge and Woodward (2000) also sampled moths in Sandy Island Provincial Park.

Rare invertebrate records in coastal sand sites in Washington, Oregon, and northern California may help to inform what rare species could be expected in BC's coastal sand sites and identify survey priorities.

FIGURE 12. MOTHS AND BUTTERFLIES IN COASTAL SAND ECOSYSTEMS: a) Sand-verbena Moth (Goose Spit, Comox); b) Edwards' Beach Moth (Sidney Spit, Gulf Islands National Park Reserve); c) Anise Swallowtail larva (Goose Spit, Comox); d) *Syngrapha celsa* (noctuid moth) feeding on yellow sand-verbena flowers (near Nootka Island). Photos a to c by N. Page; photo d by R. Vennesland.

***Species of Potential Conservation Concern.*** The following annotated list describes terrestrial invertebrate species of potential conservation concern in BC. The list was assembled using available information sources and consultation of several invertebrate experts. Some species on the list are not yet known from BC but are included because their distribution in sand ecosystems south of BC:

### BUTTERFLIES

Coastal sand ecosystems support relatively depauperate butterfly communities because of limited larval host plants and adult nectar sources. No butterflies at risk occur predominantly in sand ecosystems in BC. Pine White *(Neophasia menapia)*, Anise Swallowtail *(Papilio zelicaon)* (see Figure 12), Grey Hairstreak *(Strymon melinus)*, and Western Spring Azure *(Celastrina ladon)* are occasionally observed in sand beaches and dunes (N. Page, pers. obs.).

**Western Branded Skipper, oregonia subspecies** *(Hesperia colorado oregonia)*: a small population occurs in dry, sandy grassland at the base of ȾIX̱EṈ (Cordova Spit) (J. Miskelly, pers. comm.); considered to be more rare than current conservation ranking indicates (Miskelly, 2009); usually associated with Garry oak grasslands and open meadows; conservation status: G5T3T4, S2S3, Blue.

### MOTHS

**Sand-verbena Moth** *(Copablepharon fuscum)*: endemic to large coastal sand sites in Georgia Basin and Puget Sound; dependent on yellow sand-verbena *(Abronia latifolia)* as its sole host plant; in Canada, found at Goose Spit, Sandy Island, Cordova Spit, and James Island (2 sites); conservation status: G1G2, S1, Endangered; see Figure 12.

**Edwards' Beach Moth** (*Anarta edwardsii* syn. *Trichoclea edwardsii*): associated with coastal sand beaches from California to BC. In BC, it has been found at six coastal sand sites concentrated near Sidney but also recorded from Wickanninish Beach; conservation status: no national or provincial rank, designated as Endangered by COSEWIC (May 2009) and recently listed as Endangered under SARA Schedule 1; see status report (COSEWIC, 2009); see Figure 12.

**Island Tiger Moth** *(Grammia complicata)*: a tiger moth species found occasionally in dry coastal meadows in coastal sand sites; it was captured in dry, sandy grasslands at Goose Spit, Sandy Island, and Savary Island (N. Page, pers. comm.; Troubridge and Woodward, 2000); also found on some non-coastal Garry oak grassland sites; see Schmidt (2009) for more information; conservation status: unranked globally, nationally, and provincially; likely S1 or S2, endangered; currently on the candidate list for COSEWIC assessment.

**Beach and Dune Moths:** several noctuid moths *(Lasionycta wyatti, Euxoa wilsoni, Apamea maxima, Agrotis gravis, Lacanobia* near *atlantica, Oligia tusa, Lasionycta arietis, Hydraecia Columbia)* are associated with sand beaches and dunes on the Pacific Coast; their habitat requirements are poorly known. *Lasionycta wyatii* is associated with *Ambrosia chamissonis* Dojillo-Mooney *et al*. (1999). Troubridge and Crabo (1988) noted: "Recent study of the noctuid fauna of northwestern Washington and southwestern British Columbia has shown that several species previously known from beaches farther south in Oregon and California occur on similar beaches in our area. *Lasionycta wyatti, Euxoa wilsoni, Anarta edwardsii, Apamea maxima,* and *Agrotis gravis* are restricted to sandy ocean beaches, usually with foreshore dunes. Each of these species occurs on suitable beaches on the Strait of Juan de Fuca and the Gulf of Georgia." *Lasionycta arietis* is likely the rarest of this group and has been captured at Cheewhat dunes in Pacific Rim National Park Reserve (N. Page, pers. comm.) and by J. Sheperd in Haida Gwaii (L. Crabo, pers. comm.). It does not occur on Georgia Basin sites. *Hydraecia columbia* was not captured in a broad survey of moths of west coast of Vancouver Island and Georgia Basin beaches and dunes by N. Page, but was noted by L. Crabo as being found on beaches of the south coast of Washington. Conservation status: other than Edwards' Beach Moth, none are currently ranked.

### BEETLES

**Pacific Coast Tiger Beetle** *(Cicindela bellissima)*: occurs from coastal Washington to extreme northern California; restricted to a narrow band of discontinuous sand dunes (Pearson *et al*., 2006); not known from Canada but more sampling needed; conservation status: unranked.

**Siuslaw Sand Tiger Beetle or Siuslaw Hairy-necked Tiger Beetle** *(Cicindela hirticollis siuslawensis)*: known from Pacific Ocean beaches at the mouths of rivers from the central Washington coast south to Eureka, California (Pearson *et al*., 2006); conservation status: unranked.

***Neopachylopus sulcifrons*** (Hister beetle sp.): "This rare, ocean beach dwelling species is recorded in Canada only from Boundary Bay. Elsewhere reported south to California." (from Scudder, 1996); conservation status: unranked.

***Bledius monstratus*** (Rove beetle sp.): "In Canada, recorded only from Massett, Queen Charlotte Islands. Elsewhere reported south to central California on sea beaches." (from Scudder, 1996); conservation status: unranked.

### ROBBERFLIES

***Lasiopogon actius*** (Robberfly sp.): occurs in sand beaches of coastal BC (Haida Gwaii [RBCM]); south to California; new to Canada and BC (from Cannings, 1994); conservation status: unranked.

***Lasiopogon willametti*** (Robberfly sp.): Pacific Coast; sand beaches of Vancouver Island and sandbanks and bars of lower Fraser River and delta, southwestern BC [RBCM, UBC]. "South to northern California. New to Canada and British Columbia." (from Cannings, 1994). In Canada, recorded only from Deas Island, Ladner, and Miracle Beach (R.A. Cannings, pers. comm., 1993). Elsewhere reported from Oregon and Washington (from Scudder, 1996).

### TRUE BUGS

***Nysius paludicola*** (Seed bug sp.): In Canada, so far recorded only at Tsawwassen Beach (Scudder, 1996). Elsewhere known only from salt marshes in Washington, feeding on *Salicornia* (from Scudder, 1996); conservation status: unranked.

***Tupiocoris californicus*** (Plant bug sp.): In Canada, so far collected only at Tsawwassen Beach (G.G.E. Scudder). Also recorded from California, Colorado, and Mexico (Henry and Froeschner, 1988 in Scudder, 1996); conservation status: unranked.

***Nabicula propinqua*** (Damsel bug sp.): In British Columbia, known only from one female taken at Tsawwassen Beach in 1962 (G.G.E. Scudder). Reported from Alberta, Oregon, and many other states (Henry and Froeschner, 1988 in Scudder, 1996); conservation status: unranked.

### ISOPODS

***Alloniscus perconvexus*** (Isopod sp.): In Canada, recorded from Ferrer Point Beach, Vancouver Island, and Chatham Island near Victoria. Elsewhere, this species burrows into the sand under detritus at approximately the high tide line; occurs from southern California to Washington (Garthwaite and Lawson, 1992 in Scudder, 1996); conservation status: unranked.

***Detonella papillicornis*** (Isopod sp.): In Canada, recorded from Hammond Bay, near Nanaimo (Van Name, 1936) and Long Beach, Vancouver Island. Elsewhere this littoral species is reported from Seldovia, Cook Inlet, Alaska (Van Name 1936), and California (Garthwaite and Lawson 1992 in Scudder, 1996); considered an intertidal species; conservation status: unranked.

### SPIDERS

Based on comprehensive sampling in sparsely-vegetated habitats at Island View Beach, coastal sand ecosystems support a diverse spider community (Salomon, 2008). However, none are currently described as rare in BC and more inventory work is needed to clarify their rarity and conservation significance.

### *Knowledge Gaps and Research Priorities for Invertebrates*

1. Further inventory of invertebrates generally. Initial targets of sampling could include tiger and other ground-dwelling beetles, and spiders;
2. Detailed information on life histories and habitat requirements;
3. Threats to invertebrates inhabiting coastal sand ecosystems; and
4. Effect of exotic invertebrate species.

## Ecological Communities

As stressed throughout this report, coastal sand ecosystems support unique ecological communities[6] influenced by sand substrates and coastal processes (Ranwell, 1972; Hesp, 1991; Maun, 1994). Many are sparsely-vegetated or have open herbaceous cover with grasses, forbs, and low shrubs that tolerate sandy soils with summer drought and low nutrient availability. Vegetation development is often distinctively zonal, particularly in beaches, in response to environmental gradients inland from the shoreline. As described previously, vegetation can be generally separated into sparsely-vegetated lower beach zone, a grass-dominated upper beach zone that corresponds to the development of a beach ridge, and a dune zone that is often species-poor and sparsely-vegetated (see Figure 7) (Kuramoto, 1965; Page, 2003). Many sand beaches have only the first two zones present. Succession typically proceeds from sparsely-vegetated communities, to grass and bryophyte-dominated mat or kinnikinnick dwarf-shrubland, to shrub communities with salal and drought-tolerant conifers. Sitka spruce, western redcedar, and western hemlock are common components of late-successional ecological communities on west coast sand ecosystems, while Douglas-fir and shore pine are more common on Georgia Basin sites.

6 Ecological communities are used synonomously with the terms “plant communities” or “plant associations” for this report although there are some differences. It is also important to note that ecological communities are not currently protected by the federal Species at Risk Act.

While this report emphasizes the conservation values of sparsely-vegetated and herbaceous communities, there are a group of ecological communities associated with coastal sand ecosystems that may have important conservation values, but are not the focus of this report. They include forested communities (e.g., Sitka spruce or lodgepole pine on the west coast of Vancouver Island and Haida Gwaii or Douglas-fir and lodgepole pine in the Georgia Basin that have developed on stabilized dunes), salt marsh communities on the leeward side of protective spits (e.g., Goose Spit, Witty's Spit, Penelakut Spit, Sidney Spit, and Hook Spit), and communities on eroding sand bluffs in the Georgia Basin. These associated ecological communities may be incorporated into recovery planning in the future as more information becomes available.

***Existing Information.*** Ecological communities in coastal sand ecosystems have been poorly studied in BC compared to forests and rangelands. Some previous research has been aimed at describing and classifying ecological communities (plant associations) of western Vancouver Island beaches (Page, 2003; Kuramoto, 1965), but most has focused on few sites or used limited sampling (Hebda *et al*., 1997). More broadly, Pacific Coast beach vegetation was studied by McDonald and Barbour (1974) and Breckon and Barbour (1974), and more comprehensively in Washington, Oregon, and California by Kumler (1969), Wiedemann (1966), Wiedemann (1984), Barbour *et al*. (1976), Holton and Johnson (1979), and Christy *et al*. (1998). The BC Conservation Data Centre currently tracks four ecological communities found in coastal sand ecosystems (BC CDC, 2010).

***Descriptions.*** Eight ecological communities were described and named using a combination of data from Page (2003) on west coast Vancouver Island sites, supplemented with unpublished data from Georgia Basin (Page, unpublished; Roemer, 2000, 2001), Haida Gwaii (Golumbia, 2001), and north coast estuaries (McKenzie *et al*., 2000). They are described briefly in the following section and proceed in order from early-successional lower beach communities to later-successional shrub communities on stable dunes and forest edges. Classification was undertaken using a combination of statistical methods and hand-sorting. The results should be considered preliminary and will likely change as more surveys are undertaken. Bryophyte-dominated communities in both west coast and Georgia Basin sites may be sufficiently distinct to be considered separate ecological communities (see Kuramoto, 1965). A synoptic table of diagnostic species for the eight ecological communities is provided in Appendix 3. Diagnostic values are also noted using the categories and definitions proposed by Pojar *et al*. (1987). Representative photos are provided in Figures 13 and 14.

**American searocket *(Cakile edentula)* Sparse Vegetation:** common and widespread sparsely-vegetated community found in the lower beach; can be divided into three subcommunities (one with *Atriplex gmelini* and one with *Honckenya peploides*); European searocket *(Cakile maritima)* is also common; conservation status: unranked in BC, proposed rank S3S4.

**Dune wildrye grass — coastal strawberry *(Leymus mollis — Fragaria chiloensis)* Herbaceous Vegetation:** more of a meadow community on moist, stabilized sites; analogous to some estuary communities (see MacKenzie and Moran, 2004); yarrow (*Achillea millefolium*) a common species; conservation status: unranked in BC, proposed rank S3S4.

**Dune wildrye — beach pea *(Leymus mollis* spp. *mollis — Lathyrus japonicus)* Herbaceous Vegetation:** the dominant native beachgrass community on many coastal sites including sand and gravel beaches and some estuary sites; more common in the Georgia Basin than west coast Vancouver Island sites; rarely floristically diverse and often only with dune wildrye and beach pea present; conservation status: GNR, S1S2, Red.

**Large-headed sedge *(Carex macrocephala)* Herbaceous Vegetation:** species-poor community on upper and mid-elevation beach sites and dunes throughout coastal BC; often only with large-headed sedge present; conservation status: G1G2, S1S2, Red.

**Dune bluegrass *(Poa macrantha)* Sparse Vegetation:** dominant native dune community on the west coast of Vancouver Island and Haida Gwaii; typically very sparse cover (<10%); contains dune obligates such as black knotweed *(Polygonum paronychia)*, yellow sand-verbena, and American glehnia; conservation status: GNR, S1, Red.

**Scotch broom / sweet vernal grass *(Cytisus scoparius / Anthoxanthum odoratum)* Shrubland Vegetation:** shrubland community on Georgia Basin dunes and spits; open shrub community with grass understorey dominated by sweet vernal grass and other non-native grasses; some wildflowers present depending on density of Scotch broom; conservation status: unranked in BC, no proposed rank.

**European beachgrass *(Ammophila arenaria)* Herbaceous Vegetation:** increasingly common ecological community on the west coast of Vancouver Island that is dominated by non-native European beachgrass and American beachgrass; present occasionally in the Georgia Basin (Sidney Spit); conservation status: unranked in BC (not a native community).

**Pacific wormwood — red fescue — Racomitrium moss *(Artemisia campestris — Festuca rubra* s.l. / *Racomitrium canescens*[7]*)* Herbaceous Vegetation:** the dominant sparsely-vegetated community on dunes or spits in the Georgia Basin; highly variable in terms of species composition (for example, some sites lack Pacific wormwood); this community encompasses both sparsely-vegetated sites as well as bryophyte-dominated sites with high cover of *Racomitrium* moss; conservation status: G1, S1, Red.

**Kinnikinnick *(Arctostaphylos uva-ursi)* Dwarf Shrubland Vegetation:** successional community most often observed in west coast Vancouver Island dunes along forest margins; transitional to Salal / Oregon beaked moss shrubland (see below); tree seedlings sometimes present; few bryophytes present but relatively rich in fungi; conservation status: in interior sites, ranked as GNR, SNR, Yellow; proposed rank for coastal sites: S3.

**Salal / Oregon beaked moss *(Gaultheria shallon / Eurhynchium oreganum)* Shrubland Vegetation:** successional community that is transition between sparsely-vegetated dunes or dune meadows and forest; conservation status: unranked in BC, proposed rank S3S4.

***Ecological Communities of Potential Conservation Concern.*** The BC Conservation Data Centre currently recognizes and ranks four of the eight ecological communities as imperiled (S2) or critically imperiled (S1):

- Dune wildrye — beach pea Herbaceous Vegetation: GNR, S1S2, Red.
- Large-headed sedge Herbaceous Vegetation: G1G2, S1S2, Red.
- Dune bluegrass Sparse Vegetation: GNR, S1, Red.
- Pacific wormwood — red fescue — Racomitrium moss Herbaceous Vegetation: G1, S1, Red.

7 What has been frequently referred to as *Racomitrium canescens* is now named *Niphotrichum elongatum* (Ehrh. ex Frisv.) Bednarek-Ochyra & Ochyra; see http://oregonstate.edu/dept/botany/herbarium/racoweb/nipelo.htm. However, we use “Racomitrium” to maintain consistency with older descriptions.

### *Knowledge Gaps and Research Priorities for Ecological Communities*

Both the dune wildrye — beachpea and large-headed sedge communities are widespread and locally abundant on sand beaches throughout the BC coast; their conservation ranking may need to be reviewed. The dune communities (dune bluegrass and Pacific wormwood — red fescue — *Racomitrium* moss) are appropriately ranked. The dune bluegrass community has only been recorded at eight sites on the west coast of Vancouver Island (Page, 2003), although it can be locally abundant, such as at Wickanninish Beach dunes, and also occurs on Haida Gwaii.

Proposed ranks for the remaining ecological communities are provided above. They are based on qualitative estimates of distribution, local abundance, naturalness, and threat level. More work is needed using the conservation status assessment factors approach used by the BC CDC (see http://www.env.gov.bc.ca/cdc/documents/ConsStatusAssessFactors.pdf).

More sampling is also needed to better describe bryophyte-dominated ecological communities in dune areas of the Georgia Basin and west coast of Vancouver Island. Kuramoto (1965) recognized a bryophyte-rich association (Aira — Ceratodon Association) that developed on the dune margin behind the foredune ridge at Wickaninnish Beach. This is likely a distinct community but it is not widespread regionally. Dune slack wetland communities on Clayoquot Island should also be further inventoried, as should bluff communities in the Georgia Basin, Douglas-fir communities on ancient dune fields, and Sitka spruce forest on old beach ridges.

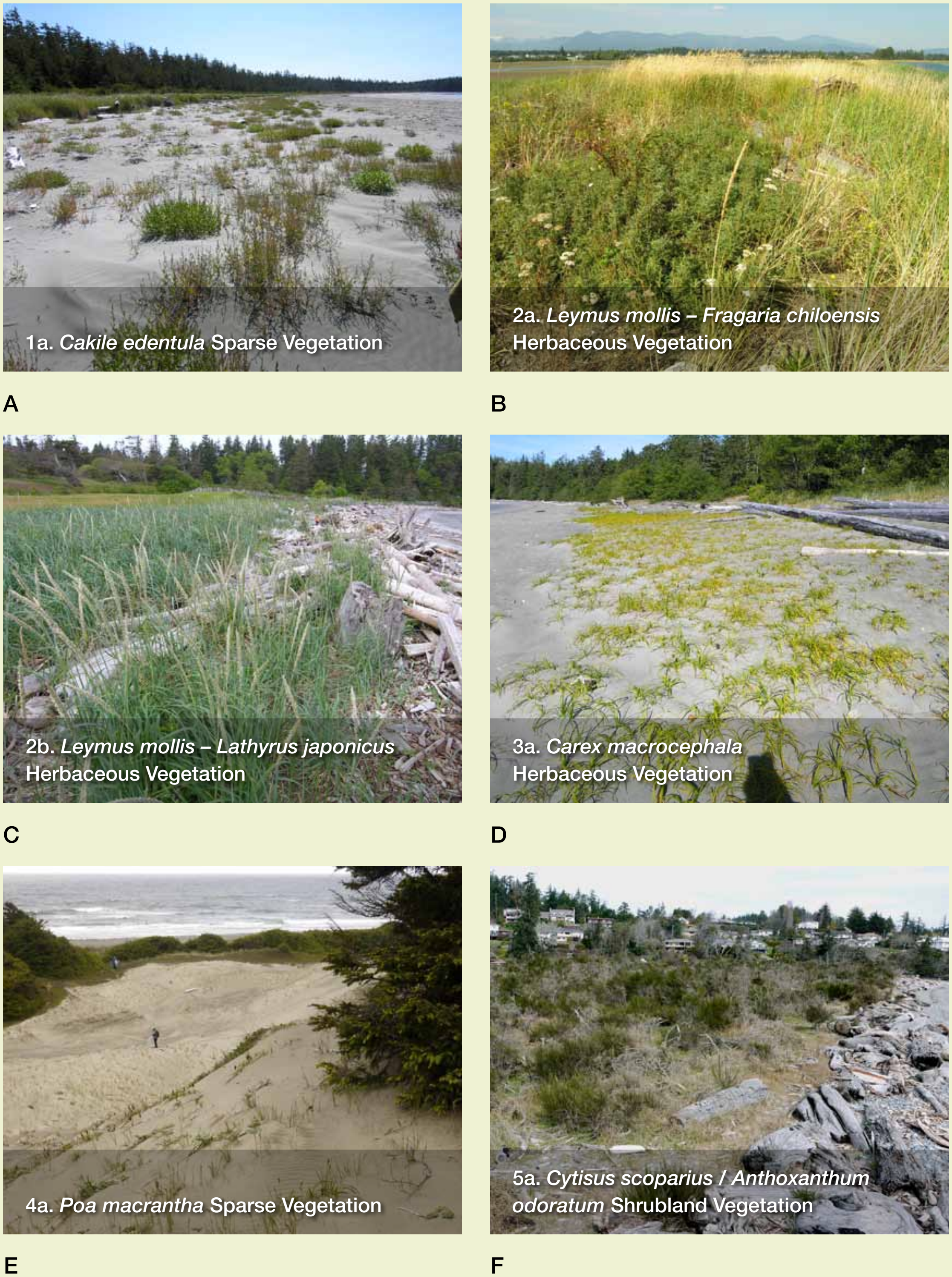
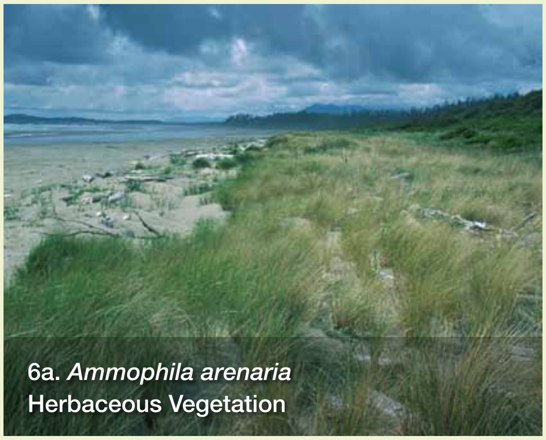



**FIGURE 13.** REPRESENTATIVE PHOTOS OF ECOLOGICAL COMMUNITIES IN COASTAL SAND ECOSYSTEMS IN BC: a) Ahous Bay, Vargas Island; b) Comox Bay; c) Little Tribune Bay, Hornby Island; d) Whitesand Cove, Flores Island; e) Wickaninnish Beach; and f) Witty's Spit, Metchosin. All photos by N. Page.




A


B


C


D

**FIGURE 14.** REPRESENTATIVE PHOTOS OF ECOLOGICAL COMMUNITIES IN COASTAL SAND ECOSYSTEMS IN BC (continued): a) Ahous Bay, Vargas Island; b) Goose Spit, Comox); c) Schooner Cove; d) Wickaninnish Beach. All photos by N. Page.

# Ethnoecology

Coastal sand ecosystems are important for First Nations as sources of plant resources and other materials, or as sites for social gatherings, spiritual activities, or habitation. Some of these uses continue to the present in sites such as Cape Mudge (Quadra Island), Goose Spit, and ȾIX̱EṈ (Cordova Spit). Coastal sand sites are associated with First Nations village or resource procurement sites, partially because their protected nature and sand substrates allowed for the beaching of large canoes and the construction of buildings or other structures on flat, well-drained ground. But many, particularly in the Georgia Basin, do not have good sources of freshwater compared to estuaries or other protected bays, which likely limited their use to short-term or seasonal activities. While this report focuses on the terrestrial component of sand ecosystems, it is difficult to separate the value of marine resources (e.g., shellfish, fish, marine birds, etc.) from the terrestrial resources such as plant foods and materials for technology. Many coastal sand sites had inter-related marine and terrestrial uses and their ethnoecological value should be considered in this context.

***Sources of Information.*** Information from ethnobotanical accounts of coastal First Nations (see Turner and Bell, 1971; Turner and Bell, 1973; Gunther, 1973; Turner *et al*., 1976; Turner, 1979; Turner and Efrat, 1982; Turner *et al*., 1983) was supplemented with direct contact with knowledgeable academics or researchers (see Appendix 2). It is important to note that First Nations were not contacted directly for ethnoecological information for this report.

***Ethnoecological Uses.*** Coastal sand sites have relatively poor resource values compared to intertidal, freshwater, or marine environments, or moist meadow habitats; fish, shellfish, and large mammals are rare in sand beaches and dunes, and plant resources are generally less abundant than in Garry oak meadows. However, coastal sand sites do contain important plant resources that are not available elsewhere.

Niscak (pers. comm.) has suggested that many coastal sand ecosystems in the Georgia Basin were richer in plant resources and more important for Coast Salish groups than has previously been believed. The co-occurrence of barestem desert-parsley *(Lomatium nudicaule)* and Hooker's onion *(Allium acuminatum)* in coastal sand ecosystems may have been a product of First Nation management similar to camas meadows. Both species were used for food by the Coast Salish. Known use sites are Goose Spit, McPhee (Little River) site in Comox, Kin Beach, Fillongley Park (Figure 14), and Sandy Island by K'omok First Nation; Sliammon people from Powell River may also have used sites on the Comox Peninsula (S. Niscak, pers. comm.). Coastal sand sites also provided resources such as grass for basketry or cordage.

Bartley (2008) recently documented the cultural importance of ȾIX̱EṈ (Cordova Spit) to the Tsawout First Nation, and suggested a new approach to ecological management and habitat restoration based on the integration of cultural and ecological values.

There is no information that indicates that coastal sand ecosystems were important for harvesting large or small mammals, terrestrial invertebrates, or birds, although it is suspected they were used as processing sites for fish, shellfish, and birds.

***Ethnobotanical plants.*** The following plant species found in coastal sand ecosystems were used by coastal First Nations:

**Yellow sand-verbena** *(Abronia latifolia)*: roots eaten by Clallam and Makah (Olympic Peninsula) (Gunther, 1945) but no records from BC; may have been used by Coast Salish (Turner and Bell, 1971).

**Hooker's onion** *(Allium acuminatum)*: commonly harvested by Coast Salish peoples and used as a food (often mixed with other plants because of its strong taste) (Turner and Bell, 1971); bulbs are often small (<1 cm in diameter).

**Barestem desert-parsley** (Indian consumption plant) *(Lomatium nudicaule)*: Turner and Bell (1971) stated that "this was one of the most powerful medicines of the Salish of southern Vancouver Island. The Saanich, Songish, and Cowichan chewed the seeds for colds and sore throats, and burned them to fumigate houses or "drive away ghosts". Seeds were swallowed for "some internal complaints"; may have been traded to west coast groups; Goose Spit and ƛIX̱EṈ (Cordova Spit) are used at present for harvesting seeds (N. Page, pers. obs.).

**Dune wildrye grass** *(Leymus mollis)*: coarse leaves used in basketry and for twine and basket straps; the Saanich and Cowichan Salish used it in the ravels of reef nets (Turner and Bell, 1971); rhizomes were important as a rub after bathing by Makah people and its harvesting may have been a form of cultivation (K. Anderson, pers. comm.).

A B

**FIGURE 15.** EXAMPLES OF PLANTS OF ETHNOBOTANICAL IMPORTANCE: a) coastal strawberries in dunes at Guise Bay, Cape Scott Provincial Park on northern Vancouver Island; and b) dense growth of barestem desert-parsely *(L. nudicaule)* at Fillongley Provincial Park on Denman Island in the traditional territory of the Comox First Nation. Both photos by N. Page.

**Silvery burweed** *(Ambrosia chamissonis)*: red sap from lower stems used in play by Nu-chah-nulth children (Turner *et al*., 1983).

**Large-headed sedge** *(Carex macrocephala)*: may have been used for basketry or other technologies.

**Kinnikinnick** *(Arctostaphylos uva-ursi)*: berries harvested for food and leaves smoked as tobacco (Turner *et al*., 1983).

**Hemlock-parsley** *(Conioselinum pacificum)*: gathered for medicinal purposes (Bouchard and Kennedy, 1990).

**Coastal strawberry** *(Fragaria chiloensis)*: berries (Figure 15) were used by most coastal First Nations as a food plant; overall value was probably limited because of low abundance, but they were cherished because of their sweet taste; important sites were often associated with sandy beaches or dunes. Genetic material from coastal strawberry has been incorporated into commercial strawberry varieties.

**Yarrow** *(Achillea millefolium)*: considered weedy and widespread and often common in grassy dune margins and similar habitats; used as a tea for respiratory ailments and other medical problems (Turner, 1979).

***Other Cultural Uses.*** Some coastal sand sites were used for cultural or social purposes. For example, Goose Spit was used for burials and was called “Graveyard Spit” in early maps. It is not known if other sites had similar uses.

# Threats

A survey of managers, stewards, and biologists undertaken as a component of this status report (Raincoast Applied Ecology, 2009) identified nine threats[8] to species and ecological communities at risk in coastal sand ecosystems, and provided a ranking of their severity based on professional judgment. Threats identified by the survey participants and their relative rank (ranging from 1 (low) to 3 (high)) are:

1. Invasive plants (2.8)
2. Coastal development (2.8)
3. Disruption to sediment transport (2.7)
4. Coastal erosion (loss of habitat) (2.5)
5. Climate change (2.4)
6. Recreation (human and dogs) (2.3)
7. Coastal erosion control (2.2)
8. Off-road vehicle use (2.0)
9. Invasive animals (1.6)

This list was refined to identify seven threat categories: (1) invasive plants; (2) disruption to coastal sediment transport; (3) recreation; (4) coastal development; (5) climate change; (6) invasive animals; and (7) atmospheric nitrogen deposition. Atmospheric nitrogen deposition was not identified in the survey but is included here. Each threat is described in more detail in the following subsections.

Population demographics, the influence of small isolated populations as a factor exacerbating the risk of extinction for species at risk, is considered an indicator of stress to some species in coastal sand ecosystems but is not addressed specifically in this report. It is a difficult factor to assess because many species in coastal sand ecosystems occur in small, spatially isolated populations. The pink sand-verbena recovery strategy (Parks Canada Agency, 2008) also identified storms as a threat to small populations on the west coast of Vancouver Island; however, because storms are considered a critical part of coastal ecology they may be more appropriately considered a limiting factor.

### INVASIVE PLANTS

Invasive plants[9] are considered the most important threat to species and ecological communities at risk in coastal sand ecosystems in BC. They can cause functional changes to ecological processes such as enhancing soil fertility and reducing sand movement, as well as competing with native plants for limited resources (moisture and nutrients), and reducing habitat plants and animals that require sparsely-vegetated ecosystems. Coastal sand ecosystems, like other frequently disturbed, ecotonal plant communities, support a disproportionately high number of exotic species (Sobrino *et al*., 2002; Grosholz, 2002). On the west coast of Vancouver Island, Page (2003) found non-native

8 A threat is any activity or process (both natural and anthropogenic) that has caused, is causing, or may cause harm, death, or behavioural changes to a species at risk or the destruction, degradation, and/or impairment of its habitat to the extent that population-level effects occur. A limiting factor is a naturally occurring process such as aging or disease that can result in normal population decline but is not considered a threat unless exacerbated by human activity.

9 Invasive plants are a small group of rapidly spreading non-native plants that become both regionally common and locally abundant and have the potential to cause changes to the composition, structure, and function of native ecosystems through competition or ecosystem effects.

plants accounted for 28% of all plant species (45 of 163) in 18 sand beaches. The most common non-native plants were American searocket *(Cakile edentula)*, European searocket (Cakile maritima), early hairgrass *(Aira praecox)*, velvetgrass *(Holcus lanatus)*, European beachgrass *(Ammophila arenaria)*, and hairy cat's-ear *(Hypochaeris radicata)* (see Page, 2003).

***Invasive Plants of the West Coast Vancouver Island and Haida Gwaii.*** European and American beachgrass (*Ammophila arenaria* and *A. breviligulata*; collectively referred to as "*Ammophila*" in this report) are the most important invasive plants in west coast Vancouver Island beaches and dunes in terms of impacts to ecosystem values. Page (2003) found that they accounted for 58% and 22% of the total plant cover, respectively, in sites where they occurred, and European beachgrass occupies almost as much area as the rest of the non-native plants combined. European beachgrass is also abundant in some areas on Haida Gwaii. In the Georgia Basin, populations of European beachgrass are established on Sidney Spit, Village (North) Spit on James Island, and Island View Beach, but populations appear to be small and stable. European beachgrass was introduced on the Pacific Coast as a sand-stabilizer for beach protection and is found from California to Alaska (Pickart, 1997). Extensive populations of American beachgrass were discovered during surveys of beach plant communities on the west coast of Vancouver Island in 2001 (Page *et al*., 2003), and it likely spread from sites in Washington and Oregon where it was first introduced. American beachgrass appears to be supplanting European beachgrass in sites in Oregon and Washington (Seabloom and Wiedemann, 1994). Both species have caused substantial changes to sand movement, beach morphology, and vegetation along sand beaches and adjacent dunes on the Pacific Coast (see summary in Pickart and Sawyer (1998); Wiedemann and Pickart, 1996). Their ability to trap sand in the upper beach (forming a foredune ridge; see Figure 16) can accelerate succession in adjacent dunes. European beachgrass can also colonize dunes away from the shoreline further contributing to stabilization (see Figure 16). European beachgrass is associated with reduced plant diversity in coastal plant communities (Barbour *et al*., 1976; Olsen, 1994). Scotch broom is also a problem in dunes near Tlell (B. Wijdeven, pers. comm.).

***Invasive Plants of the Georgia Basin.*** In the Georgia Basin, the most important invasive plants in coastal sand ecosystems are Scotch broom *(Cytisus scoparius)* and non-native grasses such as brome species (cheat grass *(Bromus tectorum)*, soft brome (Bromus hordeaceus), rip-gut brome *(Bromus rigidus)*), and sweet vernal grass *(Anthoxanthum odoratum)*. Gorse *(Ulex europaeus)*, tree lupine *(Lupinus arboreus)* (see Figure 16), and sheep sorrel *(Rumex acetosella)* are locally abundant at some sites.

Scotch broom is present in most coastal sand ecosystems (including feeder bluffs) in the Georgia Basin and is forms the dominant ecological community at Goose Spit, Hook Spit, and Witty's Spit. It also occurs sporadically in west coast Vancouver Island sites including Wickaninnish Beach, Radar Beach, and Clayoquot Island, but is never abundant and manual control efforts have been successful in controlling its establishment and spread. Scotch broom has several characteristics that make it a successful invader of coastal sand ecosystems: it is a prolific producer of long-lived seed which disperse well, it fixes nitrogen in nutrient-poor sand soils, and it is tolerant of summer drought (Haubensak and Parker, 2004; Caldwell, 2006). It forms dense stands that compete for light and moisture with native plants (Fogarty and Facelli, 1999, Sheppard *et al*., 2002), and it accelerates succession by stabilizing the surface of the sand and increasing soil fertility. However, it is important to note that Scotch broom most often colonizes sites that have been previously stabilized by native bryophytes, and is less successful in open sand areas. Work by Parker (2002) in outwash plains in central Washington found that Scotch broom invasion was facilitated by the bryophyte crust which provided suitable sites for seedling establishment. This is supported by observations of Scotch broom invasion in Georgia Basin sand spits and dunes where Scotch broom colonization often follows the development of a *Racomitrium*-dominated bryophyte mat.

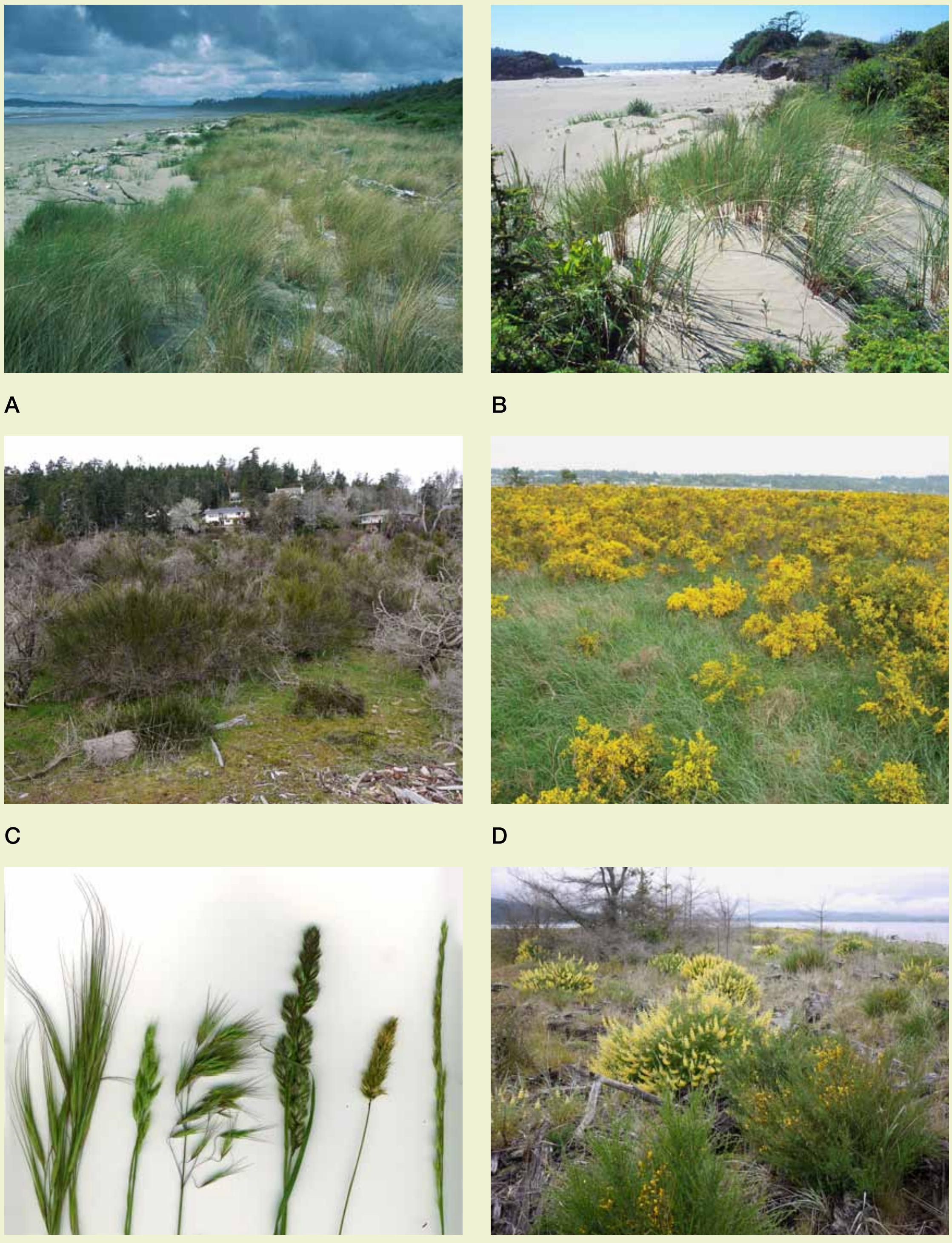



**FIGURE 16.** INVASIVE PLANTS IN COASTAL SAND ECOSYSTEMS IN BC: a) European beachgrass (Vargas Island); b) European beachgrass rapidly colonizing windblown sand (Vargas Island); c) Scotch broom (Witty's Lagoon); d) Scotch broom (Goose Spit); e) non-native grasses found in many Georgia Basin sites (from left: rip-gut brome, soft brome, cheatgrass, hedgehog dogtail, orchard grass, and rattail fescue from Goose Spit, Comox); f) tree lupine and Scotch broom (ȾIX̱EN̲ (Cordova Spit)). All photos by N. Page.

During habitat restoration trials at Goose Spit, Scotch broom seedlings that germinated after removal of the bryophyte mat rarely survived the late summer drought (N. Page, pers. obs.).

Invasive grasses are common in all Georgia Basin coastal sand ecosystems. Species commonly observed include cheat grass, soft brome, rip-gut brome, hedgehog dogtail *(Cynosurus echinatus)*,velvetgrass, orchardgrass *(Dactylis glomerata)*, sweet vernal grass *(Anthoxanthus odoratum)*, silver hairgrass *(Aira caryophyllea)*, early hairgrass, and rattail fescue *(Vulpia myuros)* (Figure 16). Most are found on stabilized sites with some soil development, however, cheatgrass and hairgrass often occur on open sand. None are considered an important driver of successional change in coastal sand ecosystems but they contribute to the development of grass-dominated meadows and organic-enriched soils over time.

Tree lupine is an important invasive species in dune systems in California and part of Oregon (Pickart and Sawyer, 1998; Pickart *et al*., 1998; Maron and Connors, 1996) but is rarely abundant in BC. It has been observed at the tip of ȾIX̱EṈ, on the Cowichan Head Bluffs, and at Goose Spit (Figure 16). It appears to decline during cold winters. Gorse occurs at North Spit on James Island and at Island View Beach (N. Page, pers. obs.).

### REDUCED SAND SUPPLY AND MOVEMENT

Coastal sand ecosystems depend on the movement of sand from source areas such as bluffs and shallow subtidal sand bars to beaches and dunes. Reduced supply or disruptions to sand movement can stabilize dunes and spits and accelerate vegetation succession, or erode the beach — dune margin (see example from Figure 17). There are four pathways that can affect sand supply and movement:

1. Reduced sand supply from source areas from natural or anthropogenic stabilization;
2. Disruption of water-born sediment movement though the intertidal zone and the lower beach;
3. Reduced movement of sand from the beach face to the vegetated upper beach and dunes (where sediment movement is dominated by wind and occasional storm events); and
4. Reduced aeolian (windblown) sand movement in dunes.

Reduced sand supply to beaches and dunes can result from shoreline protection at the base of feeder bluffs, stabilization of bluffs from vegetation establishment, or development of shoreline structures such as rock groynes that disrupt sand movement. Examples of shoreline protection affecting sand supply or movement includes armouring of the Willemar Bluffs (Comox) which appears to have reduced sand supply to Goose Spit, and reduced sand supply to Spanish Bank in English Bay because of the construction of breakwaters near Wreck Beach combined with stabilization of the Point Grey bluffs. Minor shoreline protection has also been undertaken at Cowichan Head bluffs.

Disruption of sediment movement from the lower beach (an area of water-borne sediment movement) to the vegetated upper beach and dunes (where sediment movement is dominated by wind and occasional storm events) can occur from the accumulation of wood debris, invasive plants, or shoreline structures. The development of *Ammophila*-dominated upper beach communities on many sand beaches on the west coast of Vancouver Island has likely reduced sand to dune systems. *Ammophila* species have rigid leaves that trap sand, particularly during the winter, and it rapidly colonizes windblown sand (see Figure 16). Restoration work has recently begun at Wickaninnish Beach to remove *Ammophila* and re-invigorate sediment transport processes (Beaugrand, 2010; Lee *et al*., 2010; R. Vennesland, pers. comm.).

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B

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D

**FIGURE 17.** EXAMPLES OF COASTAL EROSION CONTROL: a) 1 m high escarpment and exposed yellow sand-verbena roots at Goose Spit; b) shoreline stabilization at same site using rock armour with a layer of beach sand and wood debris (undertaken by DND); c) shoreline armouring at Willemar Bluff; and d) shoreline armouring in Beacon Hill Park, Victoria. All photos by N. Page.

## RECREATION

Recreation in coastal sand ecosystems include walking, dog walking, bird watching, camping, as well as more intensive activities such as use of motorized vehicles (e.g., trucks, ATVs), remote-controlled cars, and dune sledding or surfing. The development of recreation facilities such as boat ramps, picnic areas, and trails also occurs in coastal sand ecosystems (Figure 18). Threats from recreation include direct damage such as abrasion and crushing of plants and animals on or near the sand surface, soil compaction, fire, noise or visual disturbance to birds and other species, and removal of vegetation to increase open sand cover (e.g., for camping sites). Recreation may also act as a vector for the introduction of non-native plants; small patches of non-native grasses and forbs were often associated with campsites on the west coast of Vancouver Island (N. Page, pers. obs.).

Overall, impacts from recreation appear to be widespread but often small and localized in coastal sand ecosystems. There are no examples where recreation is considered the primary source of habitat loss or change in coastal sand ecosystems in BC. This is substantially different than in dune systems of Oregon, Washington, and California where the use of off-road vehicles has caused widespread loss of sparsely-vegetated sand ecosystems (Luckenbach and Bury, 1983). Only ȾIX̱EṈ (Cordova Spit) and Rose Spit are known to be used by off-road vehicles. At ȾIX̱EṈ, the Tsawout First Nation has implemented a successful access management program using fences, signs, and education to prevent further damage from off-road vehicles.

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**FIGURE 18.** EXAMPLES OF RECREATION-RELATED DISTURBANCE TO COASTAL SAND ECOSYSTEMS IN BC: a) small patch of yellow sand-verbena in the developed portion of Cadboro Bay Park (Victoria, BC); b) old trail colonized by bryophytes at Wickaninnish dunes; c) shoreline trail in Sandy Island Provincial Park; and d) developed recreation site at Sidney Spit. All photos by N. Page.

## COASTAL DEVELOPMENT

Coastal development encompasses the direct loss of coastal sand ecosystems from the construction of facilities such as buildings, roads, developed park areas, golf courses, parking areas, and utilities (Figure 19). Diking for agriculture or land reclamation is considered a development-related threat. Most of the impacts from coastal development occurred historically, although incremental losses continue to occur at some sites. Examples of coastal development are primarily located in the Georgia Basin and include historic diking of the Boundary Bay spit complex, construction of cadet training facilities at Goose Spit (HMCS Quadra), and development of an RV park at Island View Beach.

A

B

**FIGURE 19.** EXAMPLES OF DEVELOPMENT IN COASTAL SAND ECOSYSTEMS: a) development of roads and buildings at a coastal sand site in the Georgia Basin; b) road and building development on Goose Spit as part of Department of National Defence's cadet training facility . Photo a by N. Page and b by A. Mewitt.

## CLIMATE VARIABILITY AND CHANGE[10]

Coastal sand ecosystems are susceptible to two aspects of climate variability and change: (1) increased storm activity or intensity; and (2) sea-level rise. Trends in historical data from meteorological stations across the province show that BC's climate has warmed significantly in recent decades (Zhang *et al*., 2000; BC MWLAP, 2002; Whitfield *et al*., 2002). Longer records suggest that the rate of change in temperature and precipitation in southern BC and much of the Pacific Northwest during the twentieth century exceeded global averages (Zhang *et al*., 2000; Mote, 2003). An extensive review of climate change impacts and adaptations in BC is provided in Walker and Sydneysmith (2008).

Two major ocean-atmosphere phenomena strongly influence climate variability in BC: (1) the El Niño–Southern Oscillation (ENSO), and (2) the Pacific Decadal Oscillation (PDO). Both are naturally occurring patterns, but their frequency and intensity appear to be changing in response to global climate change (Trenberth and Hurrell, 1994; Timmermann, 1999). ENSO is a tropical Pacific phenomenon that influences global weather patterns and has a cycle of 3 to 7 years (Wolter and Timlin, 1993; Wolter and Timlin, 1998) and individual events typically persist for 6 to 18 months (Ropelewski and Halpert, 1986; Yarnal and Diaz, 1986).

10 Longer-term climate change (CC) is defined by a statistically significant variation in the mean state of climate elements over an extended period of decades to centuries. Climate variability (CV) is defined by shorter-term (i.e., seasonal to interannual) statistically significant variations in average climate conditions.

To date, little research exists on the effects of ENSO or PDO variability on coastal BC. Oceanographic responses to these events include elevations in local sea levels due to the effects of thermal expansion in warmer coastal waters and, to a lesser degree, on increased terrestrial freshwater discharge. For instance, during major El Niño events (e.g., 1982–83, 1997–98) sea levels along the west coast of North America from California to Alaska rose by as much as 100 cm (Subbotina *et al*., 2001). During the winter of 1997–98, Hecate Strait experienced a rise of ~40 cm (Barrie and Conway, 2002). Due to more intense and more frequent storms associated with an enhanced Aleutian Low pressure system and enhanced storm waves along the Pacific coast, these El Niño events produced extensive coastal erosion and infrastructure damage (Storlazzi *et al*., 2000; Allan and Komar, 2002). In Haida Gwaii, the 1997–98 El Niño caused as much as 12 m coastal retreat on northeastern Graham Island (Barrie and Conway, 2002). There can be a strong correlation between positive Pacific Interdecadal Oscillation values and elevated sea levels in Hecate Strait, although the mechanisms of the Pacific Interdecadal Oscillation are not well understood.

Marine ecosystems in the northeast Pacific respond to phase changes in the Pacific Interdecadal Oscillation (e.g., Mantua *et al*., 1997; Hare and Mantua, 2000; Gedalof *et al*., 2002). As with El Niño events (and negative Northern Oscillation Index periods) warm phases of the Pacific Interdecadal Oscillation have enhanced coastal biological productivity in Alaska whilst inhibiting productivity along the southern BC and western North American coast due to warmer coastal waters and reduced upwelling. Cold Pacific Interdecadal Oscillation phases show the opposite pattern of marine ecosystem productivity. Recently, DFO has documented that during warm ENSO years the migration route of Pacific salmon headed for the Fraser River is diverted northward around Vancouver Island via Johnstone Strait instead of Juan de Fuca Strait. In addition, unusual species such as mackerel *(Scomber japonicus)*, which prey on juvenile salmon, have been observed to migrate north in ENSO years.

Globally, mean sea level has increased 10 to 20 cm during the twentieth century, and is anticipated to rise another 18 to 59 cm by 2100 due largely to melting glaciers and ice sheets and thermal expansion of warming seawater (IPCC, 2007). In BC, relative sea-level change differs from the global trend due to vertical land movements (e.g., ground subsidence or uplift). During the twentieth century, sea level rose 4 cm in Vancouver, 8 cm in Victoria, and 12 cm in Prince Rupert, and dropped by 13 cm in Tofino (BC Ministry of Water, Land and Air Protection, 2002). Superimposed on these gradual trends in sea level, the height of extreme high-water events linked to coastal storms is increasing at a rate faster than sea-level rise (e.g., 22–34 cm/century at Prince Rupert, 16 cm/century at Vancouver; BC Ministry of Water, Land and Air Protection, 2002; Abeysirigunawardena and Walker, 2008). At Tofino, where relative sea level has fallen, the extreme high-water events show little change but appear to be correlated to the ENSO phenomenon. Elsewhere on the west coast, extreme sea levels, storm surges and enhanced coastal erosion are strongly influenced by ENSO and PDO (e.g., Storlazzi *et al*., 2000; Dingler and Reiss, 2001; Allan and Komar, 2002; Abeysirigunawardena and Walker, 2008) and have increased significantly since the positive PDO shift of 1976 (Abeysirigunawardena and Walker, 2008). During the El Niños of 1982–1983 and 1997–1998, sea levels from California to Alaska rose as much as 100 cm above average (Subbotina *et al*., 2001), and more energetic wave conditions produced extensive coastal erosion and infrastructure damage on the shores of the northwestern US (Storlazzi *et al*., 2000; Allan and Komar, 2002). On BC's north coast, sea levels rose 10 to 40 cm above seasonal heights in 1997–1998 causing extensive localized erosion (Crawford *et al*., 1999; Barrie and Conway, 2002). It is anticipated that ongoing sea-level rise trends will accelerate into the future (IPCC, 2007) and that climate variability driven extreme water level and storm events may increase in frequency and magnitude.

## ATMOSPHERIC NITROGEN DEPOSITION

Atmospheric nitrogen deposition is considered a potential, but poorly understood, threat to coastal sand ecosystems in BC.

Increased soil nutrients from atmospheric nutrient deposition (Bobbink *et al*., 1998; Jones *et al*., 2004) can cause systemic changes in sand ecosystem vegetation and soil by enhancing vegetation establishment and growth. Atmospheric nitrogen deposition is a critical problem in some dune systems in western Europe (Gerlach, 1993; ten Harkel, 1996; Veer, 1997). In the UK, for example, many active dune systems have rapidly stabilized in the past 40 years resulting in loss of sparsely-vegetated early successional habitats and their unique species (Jones *et al*., 2004). Jones *et al*. (2004) found that atmospheric nitrogen inputs were positively related to above-ground biomass in Scottish dunes, and accelerated vegetation succession and soil development by increasing soil organic matter. They suggested a critical load range of 10–20 kgN/ha/yr of nitrogen to protect coastal sand ecosystems in the UK. However, Remke *et al*. (2009) found that acidic, lichen-dominated coastal dunes along the Baltic Sea were susceptible to critical loads of 4–6 kgN/ha/yr.

The threat to coastal sand ecosystems in BC from atmospheric nitrogen deposition is poorly understood but likely low, at least at present. Raymond (2003) found that nitrogen loading at the UBC Research Forest at Haney was between 4–10 kgN/ha/yr. A rough estimate for Saturna Island between 2000–2007 was 1.3–2.3 kgN/ha/yr (mean of 1.71 kgN/ha/yr) (P. Shaw, pers. comm.). Both estimates suggest nitrogen deposition is substantially lower in coastal BC than in western Europe. However, the stabilization of many sand ecosystems in BC by vegetation in the absence of other factors such as reduced sand supply, particularly the Georgia Basin sites where atmospheric nitrogen deposition is highest, suggests more research is needed.

## INVASIVE ANIMALS

Eastern Cottontail *(Sylvilagus floridanus)*, found on southeastern Vancouver Island from Sooke to Campbell River, is the only important non-native vertebrate to effect coastal sand ecosystems. European Rabbit *(Oryctolagus cuniculus)* may also be present in some sites and is a species of management concern in sand dunes in San Juan National Historic Park on San Juan Island, WA. Rats (*Rattus* sp.) are occasionally observed in upper beach areas with extensive driftwood in the Georgia Basin (N. Page, pers. obs.). Fallow Deer *(Dama dama)* browse vegetation in coastal sand ecosystems on both James and Sidney islands in the southern part of the Strait of Georgia (N. Page, pers. obs.).

Eastern Cottontails can browse heavily on some native plants including the leaves of yellow sand-verbena and the roots of barestem desert-parsley (N. Page, pers. obs). Their presence may also affect populations of predators such as raptors by increasing prey abundance. Eastern Cottontails do not burrow and rely on shrubs and tall grasses for cover. The prevalence of Scotch broom in many coastal sand ecosystems may facilitate their use of these habitats. Browsing of yellow sand-verbena leaves in sparsely-vegetated sand ecosystems at Goose Spit appeared to decline after Scotch broom was mowed by Department of National Defense in 2009 (N. Page, pers. obs.).

# Trends

Many coastal sand ecosystems in BC have changed extensively over the past 100 years, and the extent of sparsely-vegetated communities has declined 10–95% in most sites. Rates of decline for species and ecological communities at risk are likely similar, although there are few documented examples of species extirpation[11]. As described in the previous section of this report, threats include construction of roads, buildings, and golf courses, reduced sediment transport from shoreline armouring, recreation disturbance such as trail development, and vegetation stabilization from invasive plants. Natural habitat loss from erosion has also reduced the amount of sparsely-vegetated sandy habitat at some sites including Sidney and Goose spits. Scotch broom and non-native grasses have contributed to accelerated vegetation succession and the loss of sparsely-vegetation plant communities in Georgia Basin sites, while European and American beachgrasses have changed sediment transport and plant community composition on the west coast of Vancouver Island and Haida Gwaii. Dunes, spits, and other sparsely vegetated communities were the most poorly represented of seven sensitive ecosystem types that were inventoried on southeastern Vancouver Island between 1993–1997; only 39.5 ha of dune and 111.3 ha of spit were identified by air photo analysis and field assessment (Ward *et al.*, 1998).

Sites on the west coast of Vancouver Island and Haida Gwaii have been less affected by coastal development, but invasive species, particularly European and American beachgrass, have caused substantial changes in upper beach communities and contributed to dune stabilization. It is noteworthy that an assessment of vegetation patterns at Wickaninnish Beach in 1964 found *Ammophila*-dominated areas were too limited to effectively sample for plant community classification (Kuramoto, 1965). It is now the most abundant ecological community in many sites (Page, 2003).

### ASSESSING HABITAT CHANGE

Assessing quantitative trends in the area and condition of coastal sand ecosystems in BC is difficult because of the large number of sites and the inter-relationships between natural and anthropogenic habitat changes. While there is range of inferential information on the loss of degradation of coastal sand ecosystems, quantitative data is lacking. To provide a preliminary estimate of habitat change, we examined land cover change using historic air photos at six representative sites: Goose Spit, Witty's Spit, and James Island in the Georgia Basin; and Schooner Cove, Wickaninnish Beach, and Clayoquot Island on the west coast of Vancouver Island. No assessment of habitat change in central coast or Haida Gwaii sites was undertaken because of the lack of accessible air photo records. A description of representative sites and initial results are presented in the following pages using historic air photos. Air photos from each site were scanned and orthorectified prior to a GIS-based comparison of change. Photos from each site are shown at a common scale.

11 Yellow sand-verbena is no longer present at Cheewhat Beach dunes in Pacific Rim National Park reserve although it was recorded by Turner ***et al***. (1983).

***Goose Spit.*** Goose Spit is a large sand spit on the eastern shore of Comox Bay in the northern Strait of Georgia which is supplied by sand from Willemar Bluff (Figure 20). Two processes have affected coastal sand ecosystems at the spit since 1930. First, expansion of the cadet training facility (buildings, roads, and training infrastructure associated with HMCS Quadra) increased from 0.2 ha to 6.6 ha and now encompasses approximately 25% of the total spit area. Second, forest and shrubland vegetation has increased substantially while sparsely-vegetated and bryophyte-dominated ecological communities have declined (Page, 2004). Forest has increased from <0.1 ha to 0.9 ha indicating a general trend to more stable plant communities. Scotch broom has also increased substantially, from less than 0.4 ha to 9.6 ha since 2005. This community occupied 36% of the spit in 2005. Broom invasion appears to be accelerating, although recent mowing by DND has restored some areas. Both bryophyte mat and sparsely-vegetated dune areas have declined dramatically in 70 years. Dunes have declined almost 80% to 2.2 ha and bryophyte mat communities have declined almost 50% to 7.4 ha.

***Witty's Spit.*** Witty's Spit is located in Witty's Lagoon Regional Park in Metchosin, BC and encloses a saltmarsh lagoon (Figure 21). Scotch broom invasion, beginning in the early 1950s, has caused the almost complete loss of sparsely-vegetated sand habitats on the spit. Air photos from 1946 (not shown in Figure 21) appear to show the seaward portion of the spit with sparsely-vegetated open sand, and the portion nearer the lagoon as bryophyte and grass-dominated. Scotch broom patches are visible in the central portion of the spit in 1954, and by the 1970s broom-dominated shrub communities were widespread. At present over 95% of the spit is vegetated with dense Scotch broom shrubland. A small area of sparsely-vegetated sand communities occurs at the western neck of the spit, but it is heavily disturbed by recreation. Very small populations of contorted-pod evening-primrose and yellow sand-verbena still occur in this area (Fairbarns and Vennesland, in prep.).

***James Island*** (southeast shore). James Island is a privately-owned island east of Sidney, BC. It has a series of actively eroding sand bluffs (see Figure 22) that feed three spits (Village (North) Spit, Powder Jetty Spit, and Melanie Spit), and a large dune field (Page and Harcombe, 2010). The southeastern shore of the island encompasses the dune field and Powder Jetty Spit encloses a saltmarsh lagoon. The area was initially modified in the 1920s during development of an explosives factory on the island. More recently the area has been regraded and replanted for golf course use. The loss of sparsely-vegetated communities has been extensive. Less than 33% (8.5 ha) of the 25.5 ha of open sand habitats that were present in 1926 were present in 2007; many of these have now been converted to golf course use. Despite these changes, the small spit on the northern end of the dune field continues to support healthy coastal sand ecosystems including populations of yellow sand-verbena, Sand-verbena Moth, and Edwards' Beach Moth.

***Schooner Cove.*** Schooner Cove is a protected sand beach in Pacific Rim National Park Reserve with a prominent dune. The dune is noteworthy because of its species-rich native plant communities with distinctive bryophyte-dominated hummocks surrounding long-lived silver burweed plants (Figures 11 and 23). Native sparsely-vegetated communities have declined from 4.4 ha to 1.0 ha (23% of historic extent) at Schooner Cove since 1930 (see Figure 23). Part of this change has been caused by development of European beachgrass communities on the foredune ridge which have reduced sand movement into the dune (Figure 9). Kinnikinnick expansion along the forested margin of the dune (see Figure 9), and the development of shrub and tree dominated areas (Figure 9) has also contributed to the loss of sparsely-vegetated habitats.

***Clayoquot (Stubbs) Island.*** Clayoquot Island is a unique example of a wedge-shaped sand spit formed in the protected shallow waters of Clayoquot Sound (Figure 24). It is near Tofino, BC. A review of historical air photos showed that the overall extent of the spit has expanded from 9.0 ha in 1930 to 11.7 ha in 1996 (129% increase in overall size). The configuration of the spit is also very different; it has narrowed and the central axis of the spit is approximately 100 m northwest of its position in 1930. However, despite the overall increase in size, the extent of sparsely-vegetated sand ecosystems has declined from 5.9 ha in 1930 (65% of previous spit area) to 1.5 ha in 1996 (13% of current area), with most of the open sand areas confined to the perimeter of the spit. Dune slack wetlands, a rare and undescribed ecological community, occur in the centre of the spit. The development of herbaceous, shrub, and forest communities has occurred rapidly (see Figure 24). European beachgrass was introduced to Clayoquot Island in 1940s to promote sand stabilization (Hubbard, 1969).

***Wickaninnish Beach.*** Wickaninnish Beach is a 3.5 km long sand beach with backshore dunes in Pacific Rim National Park Reserve (Figure 25). The foredunes are vegetated predominantly with dune wildrye and European and American beachgrasses and the dunes support healthy communities dominated by dune bluegrass. The Wickanninish dune complex is the largest area of active sand dunes on Vancouver Island and supports large and healthy populations of yellow sand-verbena, dune bluegrass, American glehnia, and beach morning glory. It also supports a large population of silky beach pea. The overall extent of sparsely-vegetated dunes has declined from 16.5 ha in 1930 to 9.2 ha in 2007 (56% decline). Heathfield and Walker (in review) also measured changes to open sand in the Wickaninnish dune system between 1973 and 2007 using air photos and found a 28% loss of open sand. They attributed it to stabilization linked to *Ammophila* invasion. Parks Canada has recently undertaken restoration work focusing the manual removal of *Ammophila* from the foredune ridge and cutting of tree islands to increase sand movement into the dune complex (Beaugrand, 2010; Lee *et al*., 2010; R. Vennesland, pers. comm.).


**FIGURE 20. GOOSE SPIT HABITAT CHANGE (1944–2005):** Scotch broom invasion and loss of sparsely-vegetated sand dunes at Goose Spit (Comox, BC) from 1944 to 2005. Scotch broom shrublands increased from 2 ha in 1944 to over 10 ha by 2002. A core area of sparsely-vegetated sand dunes occur in the south central part of the spit (see photo f). Mowing of Scotch broom by DND in 2006–2007 has resulted in a substantial reduction in broom around the main dune area. The locations of the photos e and f are shown with red arrows in photo d.


**FIGURE 21.** WITTY'S SPIT HABITAT CHANGE (1954–2005): Scotch broom invasion and the related loss of sparsely-vegetated sand dunes at Witty's Spit (Witty's Lagoon Regional Park) from 1954 to 2005. Scotch broom appears to have been introduced in the 1950s and was abundant by the 1970s. Only a small area (photo e) is not covered by dense broom growth at present. Photos e and f show conditions in 2008. A small patch of yellow sand-verbena is noted with the white arrow (note that endangered contorted-pod evening-primrose also occurs at this site). The location of the photos e and f is shown with red arrows in photo d.

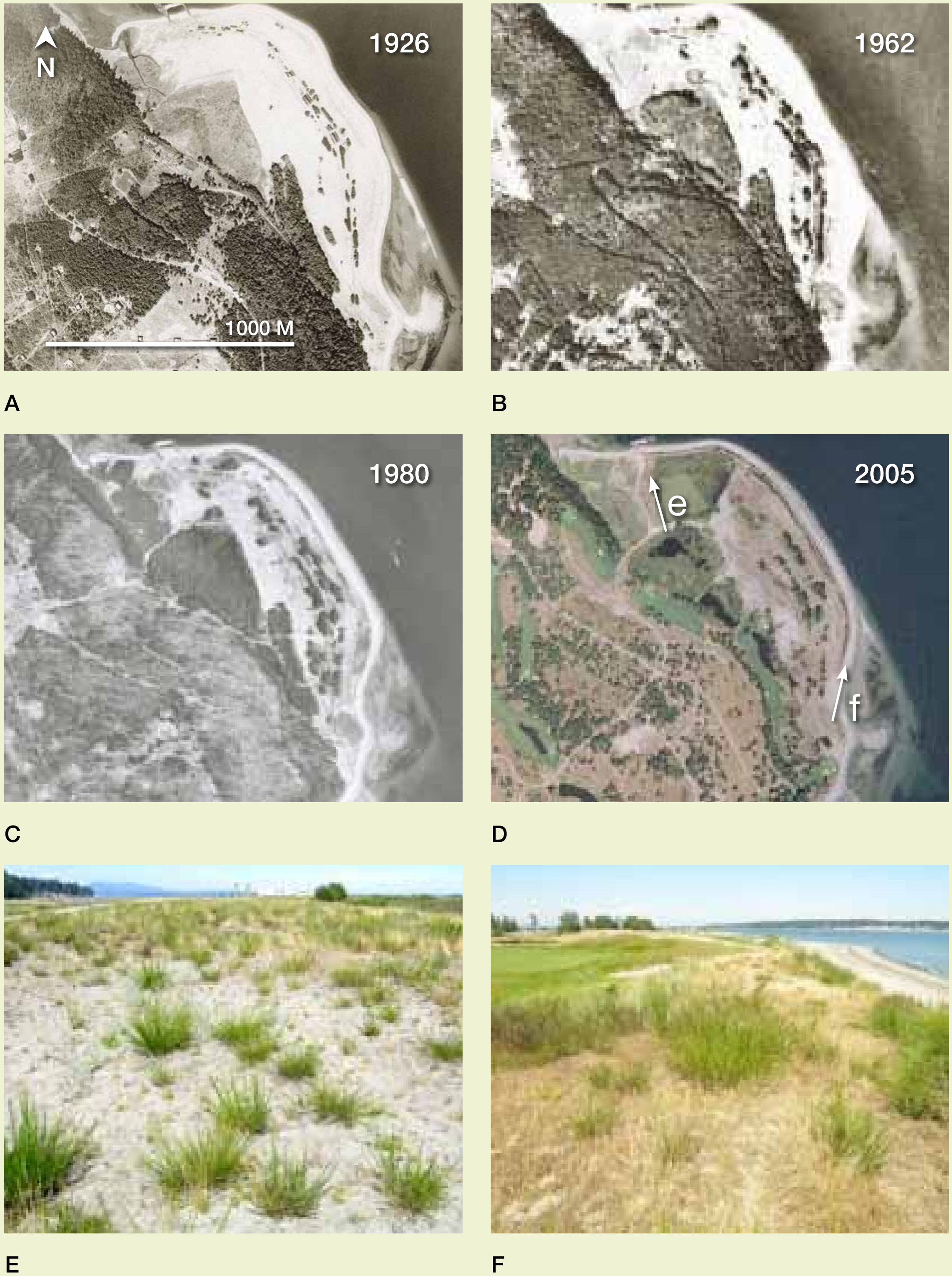



**FIGURE 22.** JAMES ISLAND (SOUTHEAST) HABITAT CHANGE (1926–2005): The dune field on the southeast side of James Island was historically an undulating dune plain fed by the large bluff to the immediate south. It encloses a saltmarsh lagoon (northwest corner) which has been partially converted to freshwater and brackish marsh. Loss of sparsely-vegetated sand communities has included industrial development (e.g., railway, buildings, and dock) during the 1930s and 1940s, and more recent conversion to golf course use (note, full extent of golf course not visible in 2005 photo). The location of the photos e and f is shown with red arrows in photo d.

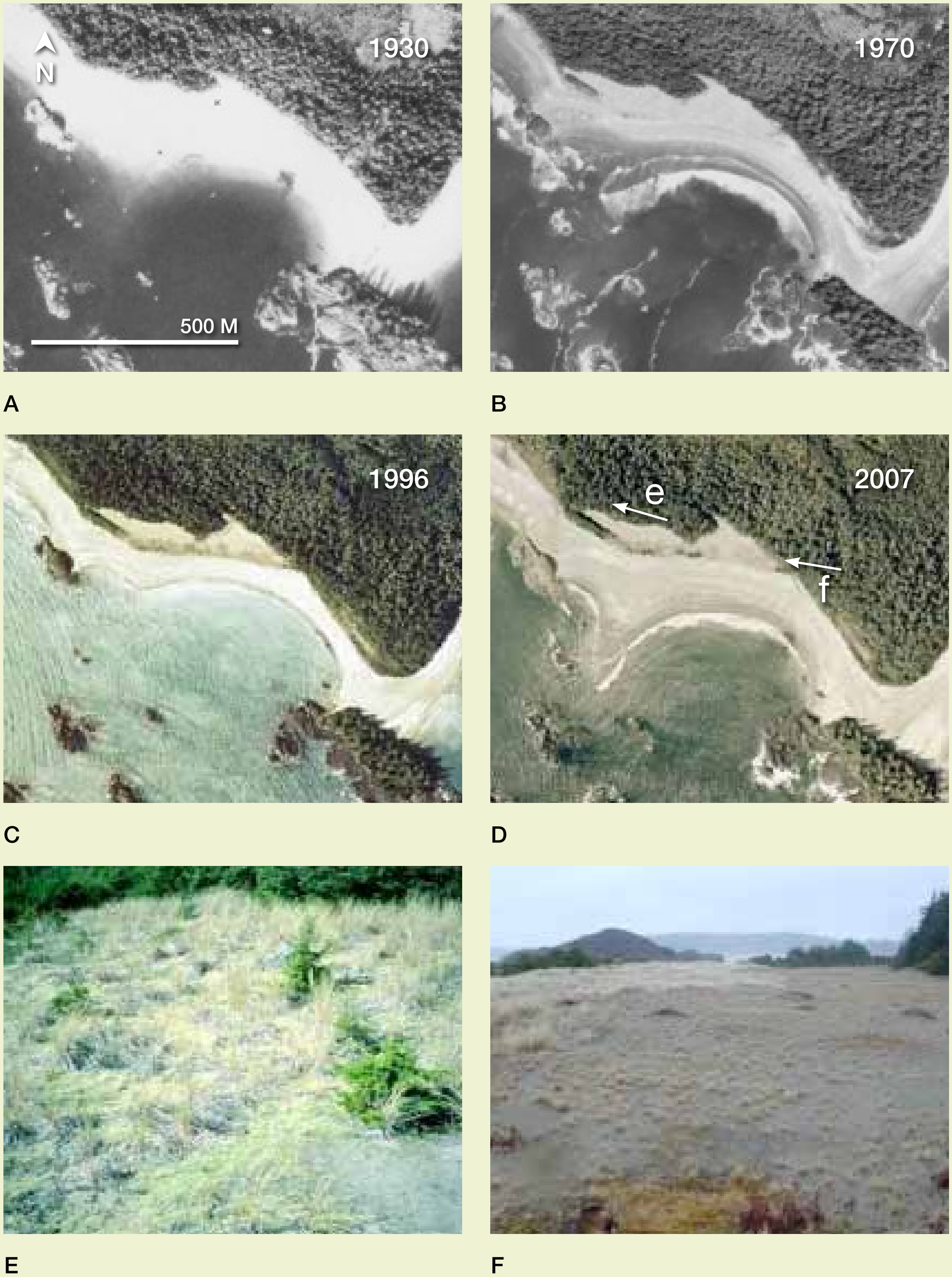
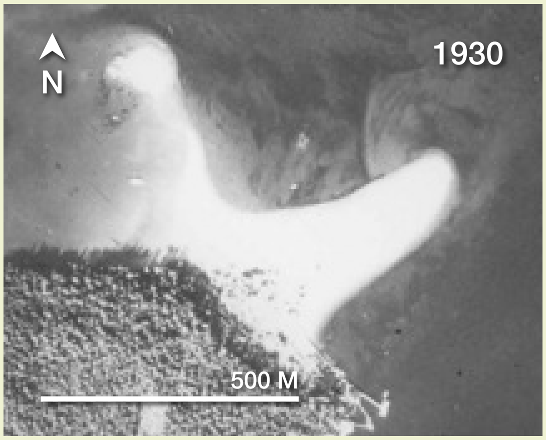



**FIGURE 23.** SCHOONER COVE HABITAT CHANGE (1930–2007): Decline of sparsely-vegetated sand dunes at Schooner Cove (Pacific Rim National Park Reserve) from 1930 to 2007. Note the complete loss of open areas on the right (southeastern portion) of the site by 2007 (blue arrow). By 2007, dunes occupied only 22% of their extent in 1930. Photos e and f show field conditions in 2001; photo f shows the distinct transition between sparsely-vegetated dunes with native dune bluegrass in the centre and right and the taller, pale coloured European beachgrass on the left. Small bryophyte-dominated hummocks can be seen in the dune. The location of photos e and f is shown with red arrows. The white arrow shows the location of a dune that is now stable.

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E

F

**FIGURE 24.** CLAYOQUOT ISLAND HABITAT CHANGE (1930–1996): Changes to configuration and habitat at Clayoquot Island sand spit from 1930 to 1997. The spit has lengthened to the east and the central axis has moved approximately 100 m northeast since 1930. Currently, sparsely vegetated ecological communities occupy only 25% of their extent in 1930. Note the extensive cover of European beachgrass (light brown tone in photo d) and the development of forest near the base of the spit. Photo e shows a dune slack (wetland) in the centre of the spit and photo f shows the well-developed foredune ridge with European beachgrass at the tip of the spit. The location of photos e and f is shown with red arrows.

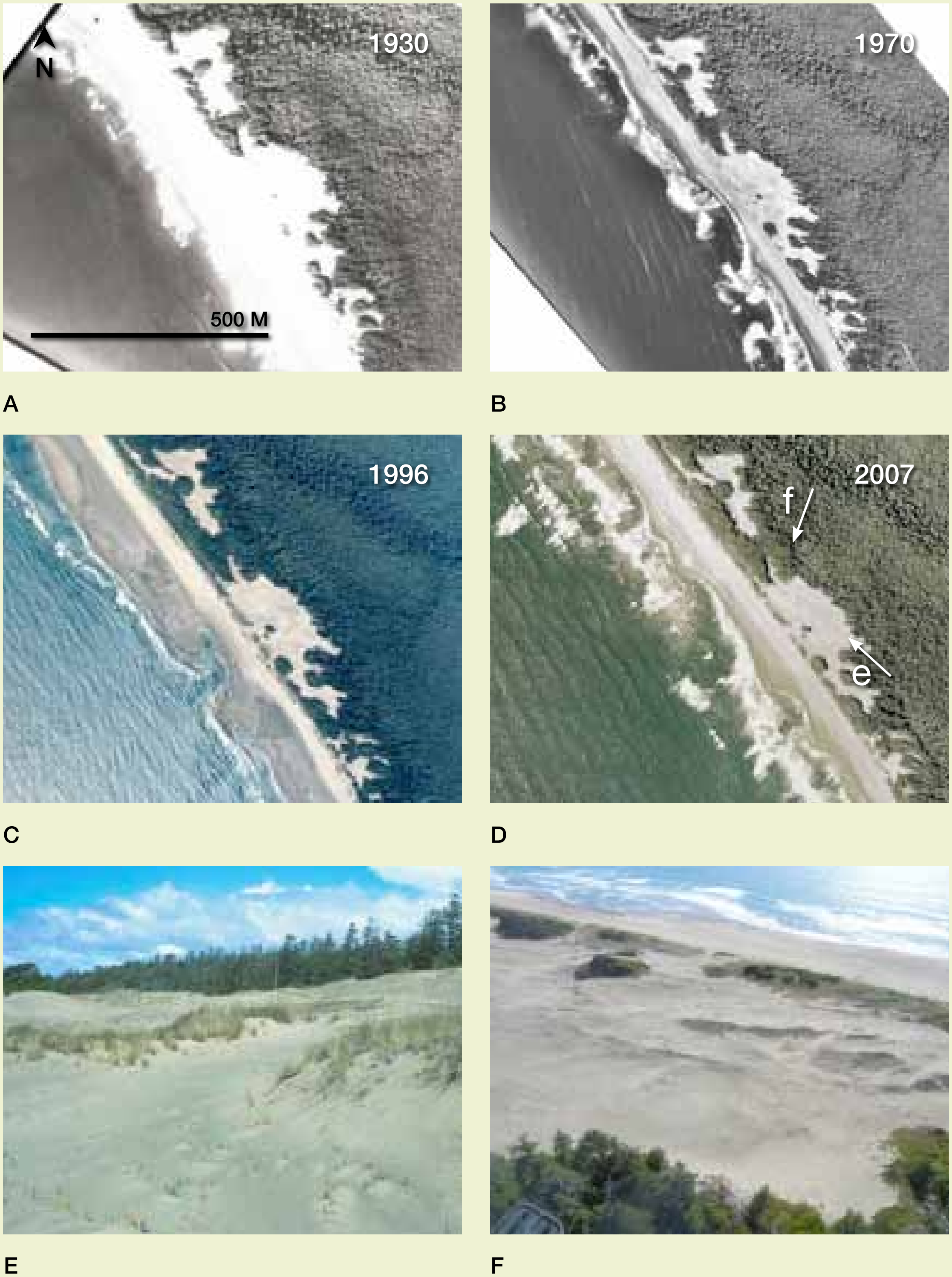


**FIGURE 25.** WICKANINNISH BEACH HABITAT CHANGE (1930–2007): Changes to the extent of open dunes at Wickaninnish Beach from 1930 to 2007. Increases in forest cover, including the development of tree islands, have reduced the extent of open dunes substantially since 1930. The location of photos e and f is shown with red arrows. Photo e is from 2001 and f is an oblique photo taken in 2007 during a helicopter overflight.

# Existing Protection and Other Status Designations

Many coastal ecosystems have formal park designation, or are owned or managed by federal, provincial, regional, or municipal governments. Table 2 provides a summary of land ownership and protection status by region for coastal sand ecosystems in BC. It is based on preliminary mapping and is expected to be refined at a later date. The dataset does not include other forms of conservation zoning such as restrictive covenants or ownership by land trusts or other conservation organizations; these include regionally important sites on Savary Island and James Island. Table 3 describes significant coastal sand ecosystems in national, provincial, and regional parks.

Overall, 85.6% of coastal sand ecosystems are protected as park, with over 73.8% of the total area designated as provincial park. The largest area is found in Naikoon Provincial Park in Haida Gwaii (1693.3 ha; 66.4% of total area of coastal sand ecosystems in BC). Another 5.1% are designated as federal or provincial Crown land including lands owned or managed by the Department of National Defence. It is noteworthy that only 6.8% of coastal sand ecosystems are privately owned; most of them are in the Georgia Basin including sites on James Island and Savary Island.

Portions of important coastal sand ecosystems on James Island (Village Spit, Melanie Spit, Powder Jetty Spit) have been recently protected by a restrictive covenant held by The Nature Conservancy of Canada and the North Pender Island Local Trust Committee (Page and Harcombe, 2010). As well, the Nature Trust of British Columbia has a 50% undivided interest in a property on Savary Island that contains the largest and least disturbed dunes in the northern part of the Georgia Basin.

**Table 2. Land ownership and protection status for important coastal sand ecosystems in BC.**
All figures are in hectares.

| Land Ownership | Georgia Basin | West Coast VI | Central Coast | Haida Gwaii | Total | Percent |
|---|---|---|---|---|---|---|
| **Private** | **154.9** | **17.4** | | | **172.3** | **6.8%** |
| **Indian Reserve** | **30.6** | **7.4** | | **26.1** | **64.1** | **2.5%** |
| Federal Crown Land | 61.7 | | | | 61.7 | 2.4% |
| Provincial Crown Land | | 5.7 | 1.6 | 61.2 | 68.5 | 2.7% |
| **Subtotal Crown Land** | **61.7** | **5.7** | **1.6** | **61.2** | **130.3** | **5.1%** |
| Municipal Park | 59.3 | | | | 59.3 | 2.3% |
| Regional Park | 84.3 | | | | 84.3 | 3.3% |
| Provincial Park | 64.2 | 100.2 | 22.8 | 1693.3 | 1880.4 | 73.8% |
| National Park | 34.7 | 114.5 | | 8.6 | 157.8 | 6.2% |
| **Subtotal Park** | **242.5** | **214.6** | **22.8** | **1701.9** | **2181.8** | **85.6%** |
| **Total** | **489.6 ha** | **245.1 ha** | **24.4 ha** | **1789.2 ha** | **2548.4 ha** | |

**Table 3. Important coastal sand ecosystems in national, provincial, or regional parks in BC.**

| PARK SYSTEM / PARK | DESCRIPTION OF COASTAL SAND ECOSYSTEMS |
|---|---|
| **NATIONAL PARKS** | |
| Pacific Rim National Park Reserve | Protects largest concentration of sand beaches and dunes on Vancouver Island including Cheewhat Dune, Keeha Bay, Pachena Bay, Florencia Bay, Wickaninnish Beach and Dunes, Schooner Cove Dunes, and Radar Beach |
| Southern Gulf Islands National Park Reserve | Protects Sidney and Hook spits on Sidney Island |
| Gwaii Hanaas National Park Reserve | Protects small number of sand dominated crescent beaches including Woodruff and Gilbert bays on Kunghit Island |
| **PROVINCIAL PARKS** | |
| Buccaneer Bay Provincial Park | Protects disturbed sand ecosystems between North and South Thormanby islands |
| Sandy Island Provincial Park | Protects the coastal sand ecosystems (dunes, beaches, dry meadows) of Sandy Island and adjacent islets |
| Vargas Island Provincial Park | Includes large crescent beaches and some active and stabilized dunes on the west coast of Vargas Island, including Ahous Bay |
| Flores Island Provincial Park | Protects a series of crescent beaches on the west coast of Flores Island including the beach and stabilized dune at Cow Bay |
| Cape Scott Provincial Park | Protects a series of sand beaches, as well as the large active dune area (sand neck) between Guise Bay and Experiment Bight |
| Hakai Luxvbalis Conservancy Area | This recent conservancy protects several sand beaches on Calvert Island on the central coast |
| Naikoon Provincial Park | Protects the largest area of sand beach and dunes in BC including East Beach, North Beach, and Rose Spit |
| **REGIONAL PARKS** | |
| Boundary Bay Regional Park | Encompasses a series of older sand spits and adjacent sand shoreline; diked and disturbed by recreation use |
| Island View Beach Regional Park | Contains sandy shoreline and some dune areas; adjacent to TIXEN (Cordova Spit) and other coastal sand ecosystems on the Tsawout IR |
| Witty's Lagoon Regional Park | Encompasses a sand spit that is now heavily colonized by Scotch broom |

# Special Significance

Coastal sand ecosystems are important for First Nations as sources of plant resources and other materials, or as sites for social gatherings, food processing, spiritual activities, or habitation. Many sites are of historical importance and some uses continue to the present.

Coastal sand ecosystems are also important areas for hiking, camping, nature watching, and other forms of passive recreation. Their representation in the federal, provincial, and regional park systems attest to their value for public use.

Sand dunes and bluffs continue to be the focus of academic research to understand the physical processes that shape coastlines, and to reconstruct the geomorphic and glacial history of the BC coast.

Finally, some coastal sand ecosystems protect adjacent houses, roads, agricultural lands, and other infrastructure from the effects of coastal flooding or storm damage.

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# Biographical Summary of Authors

**NICK PAGE** is a Registered Professional Biologist who works on the assessment and conservation of species and ecosystems in coastal BC. His project work includes watershed planning, plant community ecology, and studies of rare invertebrates. He completed a MSc in the Institute for Resources, Environment, and Sustainability at the University of British Columbia in 2003. His thesis focused on regional and local effects of exotic plant invasion in sand beach vegetation of Vancouver Island, BC. He wrote the COSEWIC status report for the Sand-verbena Moth, an endangered *Copablepharon* moth found in sand dunes and beaches of the Strait of Georgia, BC. He is also involved in the recovery of species at risk and sits on recovery teams for pink sand-verbena and Streaked Horned Lark, and is a technical advisor to the provincial invertebrate recovery team. He is currently involved in initiating the Coastal Sand Ecosystems Recovery Team. He started Raincoast Applied Ecology in 2003.

**PATRICK LILLEY** is a Registered Professional Biologist with Raincoast Applied Ecology. He has a Bachelor's degree in Environmental Sciences and most recently completed his Master's degree in Botany at the University of British Columbia in 2008. His thesis focused on the factors influencing the distribution of native and exotic plant species in Garry oak meadow habitats on southeastern Vancouver Island. He has expertise in plant ecology, biological inventories, ecological modeling, and habitat mapping. He has conducted numerous inventories of plant communities on southern Vancouver Island and is currently involved in multi-species recovery planning for three Garry oak butterfly species and coastal sand ecosystems. He is the co-chair of the Science & Research Committee of the Greater Vancouver Invasive Plant Council and a member of the Conservation Science Advisory Committee for A Rocha Canada.

**IAN WALKER** is an Associate Professor of Geography at the University of Victoria, British Columbia. He obtained his BSc from the University of Toronto in 1995 and his PhD from the University of Guelph in 2000. His research expertise includes beach-dune geomorphology, sedimentary processes, and assessing the signals and coastal impacts of climate variability and sea-level rise. In 2007 he was awarded the Canadian Geomorphology Research Group's J.R. Mackay award for significant research by an emerging geomorphologist. Dr. Walker's work in climate change impacts and adaptations includes: i) lead researcher on a multi-disciplinary team that examined environmental and community vulnerabilities on one of Canada's most sensitive coastlines to sea-level rise — Graham Island, Haida Gwaii, BC, ii) co-lead of the British Columbia Chapter in the recent NRCan Canada Report entitled, "From Impacts to Adaptation: Canada in a Changing Climate 2007", and ii) lead of a coast-wide climate change and coastal erosion monitoring network with Parks Canada in BC's three coastal National Parks (Gwaii Haanas, Gulf Islands, and Pacific Rim). His research is supported by funding and partnerships with NSERC, the Canada Foundation for Innovation, NRCan, Geological Survey of Canada, and Parks Canada. He also works closely with the Pacific Climate Impacts Consortium at UVic.

**ROSS VENNESLAND** is the Species at Risk Recovery Specialist for Parks Canada at the Western and Northern Service Centre in Vancouver. With Parks Canada, Ross plans, coordinates, and implements research and conservation actions for species and ecosystems at risk inside and outside of national parks in the Pacific-Yukon Region, working on a diverse array of creatures from jumping-slugs and insects to plants and birds. A current focus is on coastal sand ecosystems and the rare species that reside within them, including re-introducing pink sand-verbena to Pacific Rim National Park Reserve. Ross studied Biology and Biogeography at Simon Fraser University, completing his B.Sc. degree in 1996 and his M.Sc. degree in 2000. His graduate work centred on the behavioural ecology and conservation biology of the Great Blue Heron. Ross has worked extensively with species and ecosystems at risk, authoring status reports and recovery strategies and conducting numerous research and critical habitat projects. From 2002 to 2006, he worked as the Senior Ecosystems Biologist for Species at Risk in the South Coast Region of the B.C. Ministry of Environment. In that capacity, he chaired several recovery teams and co-founded and chaired the South Coast Conservation Program (www.sccp.ca), a landscape-level initiative to conserve the rich biodiversity of the region.

## APPENDIX 1. Distribution of Quadra Sand (darker-shaded pattern) in the Georgia Basin.

The inset map shows the maximum extent of the Cordilleran ice sheet during the Fraser Glaciation (from Clague *et al*., 2005).

## APPENDIX 2. Technical authorities consulted.

### ETHNOECOLOGY

Nancy Turner — University of Victoria

Glenn Bartley — independent biologist and photographer

Kat Anderson — National Plant Data Centre, University of California

Sharon Niscak — independent

### BRYOPHYTES

Terry McIntosh — independent biologist

Kella Sadler — Sadler and Associates

Bruce McCune — University of Oregon

Trevor Goward — independent biologist

Judy Harpel — US Forest Service

### VASCULAR PLANTS

Adolf Ceska — independent biologist

Frank Lomer — independent biologist

Matt Fairbarns — Aruncus Consulting

### GEOMORPHOLOGY

John Clague — Simon Fraser University

John Harper — Coastal and Ocean Resources

### FUNGI

Oluna Ceska — independent biologist

Adolf Ceska — independent biologist

### INVERTEBRATES

Robb Bennett — Ministry of Forest and Range

Rob Cannings — Royal BC Museum

Jennifer Heron — Ministry of Environment

Kristina Ovaska — Biolinx Environmental Research

Arthur Robinson — Natural Resources Canada

### MAMMALS

Dave Nagorsen — Mammalia Consulting

### BIRDS

Phil Henderson — Strix Environmental

Glenn Ryder — independent naturalist

Kevin Fort — Canadian Wildlife Service

Wendy Easton — Canadian Wildlife Service

## APPENDIX 3. Draft synoptic table of beach and dune plant associations in coastal BC.

| **Association Number** | **1a** | | **2a** | | **2b** | | **3a** | | **4a** | | **5a** | | **6a** | | **7a** | | **8a** | | **9a** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No. of Plots** | 192 | | 46 | | 121 | | 35 | | 76 | | 5 | | 103 | | 64 (51)[3] | | 36 | | 40 | |
| **1. Cakile edentula Sparse Vegetation Alliance** | | | | | | | | | | | | | | | | | | | | |
| **1a. Cakile edentula Sparse Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Cakile edentula* | V | 2 | I | r | II | 1 | II | 1 | I | | | | I | r | | | | | I | r |
| **2. Leymus mollis spp. mollis Herbaceous Vegetation Alliance** | | | | | | | | | | | | | | | | | | | | |
| *Leymus mollis* spp. *mollis* | I | r | IV | 5 | V | 5 | II | 1 | I | | | | II | 2 | I | r | I | 1 | II | 2 |
| **2a. Leymus mollis spp. mollis - Fragaria chiloensis Herbaceous Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Fragaria chiloensis* | | | III | 3 | I | 1 | I | 2 | | | | | II | 1 | | | I | r | II | 2 |
| *Achillea millefolium* | I | r | III | r | I | r | I | r | I | | I | r | I | r | | | I | r | I | r |
| **2b. Leymus mollis spp. mollis - Lathyrus japonicus Herbaceous Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Lathyrus japonicus* | I | r | I | 1 | III | 4 | I | 2 | I | | | | II | 2 | | | I | r | II | 2 |
| **3. Carex macrocephala Herbaceous Vegetation Alliance** | | | | | | | | | | | | | | | | | | | | |
| **3a. Carex macrocephala Herbaceous Vegetation** | | | | | | | | | | | I | r | | | | | | | | |
| *Carex macrocephala* | I | r | I | r | I | 1 | V | 4 | III | 2 | | | I | r | I | 2 | I | r | I | r |
| **4. Poa macrantha Sparse Vegetation Alliance** | | | | | | | | | | | | | | | | | | | | |
| **4a. Poa macrantha Sparse Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Poa macrantha* | I | r | I | r | I | r | II | 2 | V | 2 | | | I | r | | | II | 1 | I | r |
| *Polygonum paronychia* | | | I | r | I | r | I | r | III | r | | | | | I | 2 | I | r | | |
| **5. Cytisus scoparius / Anthoxanthum odoratum Shrubland Alliance** | | | | | | | | | | | | | | | | | | | | |
| **5a. Cytisus scoparius / Anthoxanthum odoratum Shrubland Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Cytisus scoparius* | | | I | 1 | I | 2 | I | r | | | V | 9 | II | 1 | I | 3 | | | | |
| *Anthoxanthum odoratum* | | | I | 1 | I | 1 | | | | | V | 5 | II | 3 | III | 3 | I | r | I | r |
| *Poa pratensis* | | | I | 3 | I | r | I | r | I | | IV | 4 | I | r | I | r | | | | |
| *Allium acuminatum* | | | | | | | | | | | IV | r | | | I | r | | | | |
| *Galium* species | I | r | I | r | I | r | | | | | III | 1 | I | 1 | I | r | | | I | r |
| **6. Ammophila arenaria Herbaceous Vegetation Alliance** | | | | | | | | | | | | | | | | | | | | |
| **6a. Ammophila arenaria Herbaceous Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Ammophila arenaria* | I | r | I | r | I | 2 | I | 3 | I | | | | V | 6 | | | III | 3 | III | 3 |
| *Aira praecox* | | | I | r | I | r | | | I | | | | III | 1 | III | r | II | r | II | 1 |
| **7. Artemisia campestris - Festuca rubra s.l. / Racomitrium canescens Herbaceous Vegetation Alliance** | | | | | | | | | | | | | | | | | | | | |
| **7a. Artemesia campestris - Festuca rubra s.l. / Racomitrium canescens Herbaceous Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Bromus* species | I | r | I | r | I | r | I | r | | | II | r | | | V | 2 | | | | |
| *Racomitrium canescens* | | | | | I | r | I | r | I | | | | II | 1 | IV | 7 | II | 5 | I | r |
| *Festuca rubra* s.l. | I | r | III | 4 | I | 1 | II | 2 | | | | | | | IV | 3 | I | r | I | r |
| *Artemisia campetris* | | | | | I | r | | | | | | | | | IV | 4 | | | | |
| *Collinsia parviflora* | | | | | I | r | | | I | | | | | | IV | r | | | | |
| *Rumex acetosella* | | | I | r | I | r | I | r | I | | I | r | II | r | IV | 2 | I | r | I | r |
| *Cladonia* species | | | | | I | r | | | | | | | II | r | III | 2 | II | r | II | r |
| *Lupinus littoralis* | | | | | I | r | I | r | | | | | | | III | 1 | I | r | | |
| *Lomatium nudicaule* | | | | | I | r | | | | | | | | | III | 3 | | | | |
| *Claytonia rubra* | | | | | I | r | | | | | | | | | III | r | | | | |
| **8. Arctostaphylos uva-ursi Alliance** | | | | | | | | | | | | | | | | | | | | |
| **8a. Arctostaphylos uva-ursi Dwarf Shrubland Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Arctostaphylos uva-ursi* | | | I | 1 | | | | | I | 2 | | | I | r | | | V | 8 | II | 1 |
| **9. Gaultheria shallon / Eurhynchium oreganum Shrubland Vegetation Alliance** | | | | | | | | | | | | | | | | | | | | |
| **9a. Gaultheria shallon / Eurhynchium oreganum Shrubland Vegetation** | | | | | | | | | | | | | | | | | | | | |
| *Gaultheria shallon* | | | II | 3 | I | 1 | I | 1 | | | | | I | 1 | | | II | 3 | IV | 5 |
| *Eurhynchium oreganum* | I | r | I | 3 | I | 2 | | | | | | | II | 2 | | | II | 4 | V | 5 |
| *Picea sitchensis* | | | I | 1 | I | r | I | r | | | | | I | r | | | I | 1 | III | 4 |
| *Vaccinium ovatum* | | | | | | | | | | | | | I | r | | | II | 1 | III | 3 |

**Notes:**

[1] PP = Presence class as percent frequency in association: I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80%, V = 81-100%.

[2] SC = Species significance class as mean percent cover: r = 0.1-0.3%, 1 = 0.4-1%, 2 = 1.1-2.1%, 3 = 2.2-5%, 4 = 5.1-10%; 5 = 10.1- 20%, 6 = 20.1-33%, 7 = 33.1-50%, 8 = 50.1-70%, 9 = 70.1-100%.

[3] PP values are described from 64 plots including presence-absence plots from Savary Island; SC values are described from 51 plots from which quantitative estimates of plant cover are available (Sandy Island and Goose Spit).

## APPENDIX 4. Distribution of coastal sand ecosystems in BC

| Site Name | Level of Protection | Region | Name Code |
|---|---|---|---|
| **Georgia Basin (GB) Sites** | | | |
| Witty's Spit | Regional Park | GB | GB1 |
| Albert Head Lagoon | Regional Park | GB | GB2 |
| Esquimalt Lagoon | Municipal Park | GB | GB3 |
| Fort Rodd Hill | Federal (Historic Site) | GB | GB4 |
| Dallas Road | Unknown | GB | GB5 |
| Haynes Park | Municipal Park | GB | GB6 |
| Willows Beach | Municipal Park | GB | GB7 |
| Cadboro Bay | Municipal Park | GB | GB8 |
| TIXEN (Cordova Spit) + Island View Beach | Municipal Park; Regional Park; Indian Reserve; Private | GB | GB9 |
| James Island - West Spit | Private | GB | GB10 |
| James Island - Powder Dock | Private | GB | GB11 |
| James Island - North Spit | Private | GB | GB12 |
| Sidney Spit (south) | Unknown | GB | GB13 |
| Hook Spit | National Park | GB | GB14 |
| Sidney Spit | National Park | GB | GB15 |
| Kuper Island | Indian Reserve | GB | GB16 |
| Boundary Bay | Regional Park; Private | GB | GB17 |
| Sand Heads | Crown | GB | GB18 |
| Steveston Park | Municipal Park | GB | GB19 |
| Iona Island | Federal (Port); Regional Park | GB | GB20 |
| Wreck Beach | Regional Park | GB | GB21 |
| Spanish Bank | Municipal Park | GB | GB22 |
| Vanier Park | Municipal Park | GB | GB23 |
| West End Beaches | Municipal Park | GB | GB24 |
| North Nanaimo | Municipal Park? | GB | GB25 |
| Rathtrevor Beach | Provincial Park | GB | GB26 |
| Mapleguard Spit | Private | GB | GB27 |
| Whaling Station Bay | Private | GB | GB28 |
| Tribune Bay | Provincial Park; Private | GB | GB29 |
| Fillongley Park | Provincial Park | GB | GB30 |
| Denman Island (west) | Private | GB | GB31 |
| Longbeak Point | Private | GB | GB32 |
| Sandy Island | Provincial Park | GB | GB33 |
| Goose Spit | Regional Park; Department of National Defense; Indian Reserve | GB | GB34 |
| Point Holmes | Private | GB | GB35 |
| Kye Bay | Crown? | GB | GB36 |
| Airport Beach | Department of National Defense | GB | GB37 |
| Kin Beach | Municipal Park | GB | GB38 |
| Little River sites | Private | GB | GB39 |
| Oyster River 4 | Unknown | GB | GB40 |
| Woodhus Slough | Private | GB | GB41 |
| Oyster River 2 | Private | GB | GB42 |
| Shoreline Park | Municipal Park | GB | GB43 |
| Rebecca Spit | Provincial Park | GB | GB44 |
| Marina Island | Private | GB | GB45 |
| Hernando Island (northeast) | Unknown | GB | GB46 |
| Hernando Island (southeast) | Unknown | GB | GB47 |
| Savary Island (Indian Pt) | Unknown | GB | GB48 |
| Savary Island (southwest) | Private | GB | GB49 |
| Savary Island (Meadow Spr | Unknown | GB | GB50 |
| Savary Island | Private | GB | GB51 |
| Savary Island (Beacon Poi | Unknown | GB | GB52 |
| Harwood Island | Unknown | GB | GB53 |
| Vaucroft Beach | Provincial Park (minor) | GB | GB54 |
| Buccaneer Bay | Provincial Park | GB | GB55 |
| Gill Beach | Private | GB | GB56 |
| **West Coast Vancouver Island (WC) Sites** | | | |
| Port Renfrew | Federal Park; Indian Reserve | WC | WC1 |
| Cheewhat Beach | Federal Park | WC | WC2 |
| Carmanah Beach | Federal Park | WC | WC3 |
| Pachena Bay | Federal Park | WC | WC4 |
| Keeha Bay | Federal Park | WC | WC5 |

## APPENDIX 4. Distribution of coastal sand ecosystems in BC (cont.)

| Site Name | Level of Protection | Region | Name Code |
|---|---|---|---|
| **West Coast Vancouver Island (WC) Sites (cont)** | | | |
| Tapaltos Bay | Federal Park | WC | WC6 |
| Florencia Bay | Federal Park | WC | WC7 |
| Wickanninish Beach | Federal Park | WC | WC8 |
| Long Beach | Federal Park | WC | WC9 |
| Schooner Cove | Federal Park | WC | WC10 |
| Radar Beach | Federal Park | WC | WC11 |
| Cox Bay | Private | WC | WC12 |
| Chesterman Beach | Private | WC | WC13 |
| Clayoquot Island | Private | WC | WC14 |
| Yarksis Beach | Indian Reserve | WC | WC15 |
| Ahous Bay | Provincial Park | WC | WC16 |
| Ahous Dune | Provincial Park | WC | WC17 |
| Whaler Islet | Provincial Park | WC | WC18 |
| Whitesand Cove | Indian Reserve | WC | WC19 |
| Flores Island 2 | Provincial Park | WC | WC20 |
| Flores Island 3 | Provincial Park | WC | WC21 |
| Cow Bay | Provincial Park | WC | WC22 |
| Hesquit Peninsula 2 | Provincial Park | WC | WC23 |
| Hesquit Peninsula 1 | Provincial Park | WC | WC24 |
| Barchester Bay | Provincial Park | WC | WC25 |
| Escalante River | Crown land | WC | WC26 |
| Nootka Island 2 | Provincial Park | WC | WC27 |
| Nootka Island 1 | Provincial Park | WC | WC28 |
| Benson Point | Unknown | WC | WC29 |
| Rugget Point 1 | Provincial Park | WC | WC30 |
| Battle Bay | Provincial Park | WC | WC31 |
| Brooks Peninsula 1 | Provincial Park | WC | WC32 |
| Brooks Peninsula 2 | Provincial Park | WC | WC33 |
| Driftwhale Bay | Provincial Park | WC | WC34 |
| Grant Bay | Provincial Park | WC | WC35 |
| Raft Cove | Provincial Park | WC | WC36 |
| Sand Josef Bay | Provincial Park | WC | WC37 |
| Guise Bay | Provincial Park | WC | WC38 |
| Experiment Bight | Provincial Park | WC | WC39 |
| Nels Bight | Provincial Park | WC | WC40 |
| Nissen Bight | Provincial Park | WC | WC41 |
| North Coast trail beach | Provincial Park | WC | WC42 |
| **Central Coast (CC) Sites** | | | |
| Cape Caution Beaches | Provincial Conservation Area | CC | CC1 |
| Calvert Island 3 | Provincial Conservation Area | CC | CC2 |
| Calvert Island 2 | Provincial Conservation Area | CC | CC3 |
| Calvert Island 1 | Provincial Park | CC | CC4 |
| Calvert Island 2 | Provincial Park | CC | CC5 |
| Calvert Island - west bea | Provincial Park | CC | CC6 |
| Calvert Island - north be | Provincial Park | CC | CC7 |
| Unknown Central Coast | Unknown | CC | CC8 |
| **Haida Gwaii (HG) Sites** | | | |
| Kunghit Island 2 | National Park | HG | HG1 |
| Kunghit Island 1 | National Park | HG | HG2 |
| Gilbert Bay | National Park | HG | HG3 |
| East Beach 1 | Provincial park | HG | HG4 |
| East Beach 2 | Provincial Park | HG | HG5 |
| Rose Spit | Provincial Park | HG | HG6 |
| South Beach | Provincial Park | HG | HG7 |
| Masset | Unknown | HG | HG8 |
| Lepas Bay | Ecological Reserve | HG | HG9 |
| Graham Island 1 | Crown | HG | HG10 |
| Graham Island 2 | Crown | HG | HG11 |
| Graham Island 3 | Crown | HG | HG12 |
| Graham Island 4 | Crown | HG | HG13 |