PACIFIC COAST JOINT VENTURE

Alaska • British Columbia • California • Hawaii • Oregon • Washington

HABITAT & POPULATION OBJECTIVES
Wetland Birds and Waterbirds

North Puget Lowlands Ecoregion

December 2013

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TABLE OF CONTENTS

Click on page numbers to navigate

EXECUTIVE SUMMARY

The North Puget Lowlands (NPL) Focus Area of northwestern Washington includes all of San Juan and Island counties, and those parts of Whatcom, Skagit, and Snohomish that lie west of the Cascade Mountains. The Focus Area is dominated ecologically, socially, and culturally by Puget Sound and its associated inland waters. Wetland loss in NPL far exceeds the national average. Over 80% of all tidal and freshwater wetlands have been lost since Euro-American settlement, mostly to agriculture. Most wetland loss occurred between the late 1800's and early 1900's and coincided with a period of intense agricultural expansion. Today, much of NPL is characterized by estuaries that are terminated on their landward side by earthen dikes that protect thousands of acres of farmlands from the tide.

For the purpose of this plan, the PCJV distinguished goals and objectives. Plan goals are conceptual statements that guide the establishment of quantifiable conservation objectives. However, conservation goals and objectives in the NPL implementation plan were based on the same three factors; 1) the habitat needs of priority bird species, 2) NPL's historic wetland complex and changes to that wetland complex since Euro-American settlement, and 3) the forecasted effects of sea-level rise (SLR) on coastal habitats. Agricultural lands, in conjunction with existing wetlands, provide important habitats for many of NPL's priority bird species. For some species of dabbling ducks and geese, agricultural habitats provide the bulk of food resources and population objectives for these species cannot be met in the absence of farmlands. In addition, many of NPL's key wetland types have undergone dramatic declines since settlement with loss rates approaching 100% for some wetland classes. Finally, SLR will result in further loss of coastal habitats in NPL unless opportunities are provided for the inland migration of tidal wetlands.

Three conservation goals were established for NPL; 1) preservation of agricultural landscapes, 2) a wetland complex that reflects the relative abundance of important wetland classes that historically occurred in NPL, and 3) increased resiliency of NPL coastal habitats to SLR. Although the PCJV chose not to quantify a farmland protection objective, it did establish the following objectives on behalf of agricultural lands; a) inform policy makers and resource managers about the role of agriculture in meeting the needs of priority bird species in NPL, and b) expand funding for farmland easement programs in NPL. Wetland restoration objectives were quantified in support of the PCJV's goal to develop a more balanced wetland complex. These restoration objectives would restore 50% of the historic wetland complex, and would reflect the relative abundance of major wetland types prior to settlement. These restoration objectives include; a) 3,500 acres of estuarine intertidal emergent wetlands, b) 6,000 acres of estuarine intertidal scrub shrub wetlands, and c) 14,500 acres of palustrine scrub shrub wetlands, and d) 4,900 acres of palustrine forested wetlands. Finally, a 5,000 acre farmland easement objective was established for agricultural lands that border major estuaries in NPL. Such easements would prevent development of these shorefront properties, and preserve future opportunities for the inland migration of coastal wetlands that are needed to offset the effects of SLR.

Wetland restoration objectives (acres) for North Puget Lowlands

Wetland Class	Current	Historical	25% Restoration	50% Restoration
Estuarine Intertidal Emergent	9,700	26,300	Achieved	3,500
Estuarine Intertidal Scrub-Shrub	300	12,500	2,800	6,000
Palustrine Scrub-Shrub	2,700	34,300	5,900	14,500
Palustrine Forested	2	9,800	2,500	4,900

INTRODUCTION

History of Pacific Coast Joint Venture (PCJV) Planning

The Pacific Coast Joint Venture (PCJV) adopted its first strategic plan in 1993. The plan covered wetland habitats in coastal areas of Washington, Oregon and parts of northwestern California, as well as the Fraser River Valley and other important coastal areas of British Columbia. The plan included wetland habitat and waterfowl population objectives that were based on previous plans, as well as the collective professional judgment of biologists, policy makers and wildlife managers from the agencies and conservation organizations making up the original PCJV Management Board.

The 1993 plan focused mainly on waterfowl conservation in wetland habitats, with limited or no development of biological objectives for other species or other habitats. Since then the scope of the PCJV has been expanded beyond ducks and geese to include other avian species and habitats. The PCJV has also expanded geographically, which resulted in the development of new implementation plans for southeast Alaska (2003), and Hawaii (2005). The rest of Alaska was added to the PCJV boundary in 2010, and planning for this region is in the developmental stages.

The 1993 plan included 13 Focus Areas that extended from the Queen Charlotte Islands in British Columbia to the Northern California coast. As part of the PCJV plan update, the original U.S. focus areas have been collapsed into five spatial planning units that are partially based on Level III Ecoregions designated by the Environmental Protection Agency. These include the North Puget Lowlands, South Puget Lowlands, Coast Range, Willamette Valley, and Klamath Mountains (Figure 1). Implementation plans are being developed separately for wetland dependent and upland dependent bird groups in each of these planning units, though no plan will be developed for wetland dependent birds for the Klamath Mountains. Plans for Hawaii and Alaska will continue to be developed independent of these five planning units. This plan addresses the habitat needs of waterfowl and shorebirds in the North Puget Lowlands.

Figure 1. Level III ecoregions that correspond to spatial planning units in the Pacific Coast Joint Venture

Structure of the North Puget Lowlands Plan

In 2005 the North American Waterfowl Management Plan (NAWMP) underwent the first assessment in its 20 year history. The assessment focused on Joint Ventures and their collective efforts to meet the needs of North America's waterfowl. Members of the NAWMP Assessment steering committee identified several traits that they believed were important to Joint Venture success. These "traits" were used to develop a matrix that outlined the desired characteristics of a Joint Venture implementation plan. At the same time the USFWS introduced its Strategic Habitat Conservation framework or SHC. The SHC framework argued for a more strategic approach to habitat conservation where the emphasis on more – more protection, more restoration – gives way to the science of "how much more" and "where?" SHC relies on an iterative cycle of Biological planning, Conservation Design, Habitat Delivery, and Monitoring and Research to achieve landscapes that meet a predetermined goal – e.g. supporting bird populations at some desired level – and which are sustainable.

The Joint Venture matrix and SHC share the same principles for developing effective conservation programs. Moreover, all elements of the matrix can be placed under one of SHC's four major components. The structure of the NPL plan reflects this integration. Biological Planning and Conservation Design serve as primary headings in the plan, while elements of the Joint Venture matrix occur as subsections under these headings (Figure 2). Monitoring and Research is addressed in a separate PCJV document.

Within the Biological Planning section the spatial planning unit is defined and the seasonal importance of the unit to birds described (e.g. breeding, staging, wintering). Population objectives for priority bird species are also established, while factors thought to limit these populations are explicitly stated in the context of species / habitat models. The Conservation Design section includes a description of the existing landscape and its capacity to support bird populations at desired levels. The section also includes an explicit set of conservation goals and objectives.

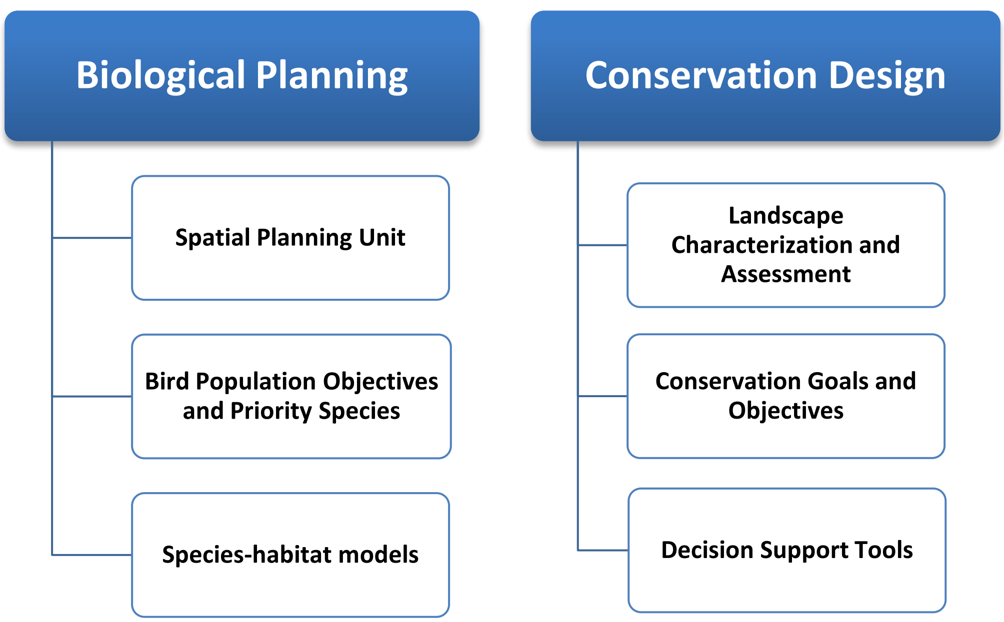

Figure 2. Organization of the PCJV Implementation Plan.

BIOLOGICAL PLANNING

Spatial Planning Unit

This section provides a general description of NPL and defines its geographic location within the PCJV boundary. Historic and current habitat conditions are also compared and habitat changes are evaluated from a bird perspective. In many cases it is simply not possible to restore landscapes in ways that closely resembles 'historic" conditions. Irreversible changes in hydrology, alternative land uses, and political realities often prevent the re-creation of historic conditions on anything but very small scales. Still it is important to understand how birds were adapted to these historical landscapes and to design conservation programs that reflect these adaptations.

Landscape

The NPL Focus Area includes Whatcom, Skagit, Island, San Juan, and Snohomish counties and totals 16,390 square kilometers (6328 square miles) or 10% of the total land area of Washington State. The region includes the west slope of the Cascade Mountains, the floodplains of major Puget Sound Rivers, the northern part of Puget Sound, the large islands of San Juan and Island counties, and the straits that encircle the San Juan Islands and connect the inland waters of British Columbia to the Strait of Juan de Fuca (Figure 3). This plan is mostly concerned with the wetland and agricultural habitats that occur at NPL's lower elevations, and which are important for wetland dependent birds. A separate plan was developed for upland bird species that includes habitats at higher elevations within NPL.

The west slopes of the northern Cascades are generally steep, rugged, and densely timbered with Douglas-fir, western hemlock, western red cedar, silver fir, and other coniferous species. Public forest land in NPL is managed primarily for timber production**,** wildlife habitat, and public recreation. Approximately 52% of the land area of Whatcom, Skagit, and Snohomish counties is owned and managed by the U.S. Forest Service and the National Park Service.

Figure 3. North Puget Lowlands spatial planning unit.

The area between the Cascade foothills and Puget Sound is relatively narrow and dominated by the floodplains of major rivers draining the western slopes of the Cascades, including the Nooksack, Skagit, Stillaguamish, and Snohomish Rivers. Although the floodplains of these rivers are highly productive, they have all been altered by draining, diking, and development for agriculture and human settlement.

The NPL focus area is dominated ecologically, socially, and culturally by Puget Sound and its associated inland waters. Six important bays, Lummi, Bellingham, Samish, Padilla, Skagit, and Port Susan, provide a mixture of tidal habitats that are critical to waterfowl and shorebirds. The islands of the NPL, including the San Juan Islands, are rural in nature but are subject to high visitor use. Other than Whidbey Island the islands are accessible only by boat or air.

The climate of the NPL focus area is mild and relatively dry for western Washington. Because the region is in the rain shadow of the Olympic Mountains, annual rainfall is typically less than for other areas of the Pacific Coast. Rainfall at sea level varies from 89 centimeters (35 inches) per year at Bellingham to 66 centimeters (26 inches) per year at Anacortes and Friday Harbor. The west slope of the Cascades is subject to heavy rains and winter snowfall. Mount Baker and other peaks in the North Cascades have permanent snowcaps during most years.

Wetland loss in NPL far exceeds the national average. Over 80% of all tidal and freshwater wetlands have been lost since Euro-American settlement, mostly to agriculture. Most wetland loss occurred between the late 1800's and early 1900's and coincided with a period of intense agricultural expansion. By 1950 wetland loss in NPL was largely complete (Collins 2000). Today, much of NPL is characterized by estuaries that are terminated on their landward sides by earthen dikes that protect thousands of acres of farmland from the tide. Historically, the large undiked river deltas of this region were dynamic systems. Dikes now largely prevent the natural creation and destruction of wetland complexes once associated with the river deltas, which were constantly changing due to storm/flood events and beaver activities

Historic and Current Bird Use

Dabbling Ducks

Although some dabbling ducks do breed in NPL the area is mostly important for migrating and wintering birds. There are no historic estimates of the number of dabbling ducks using NPL but information on pre-settlement wetlands and waterfowl foraging ecology provide some insight into how bird use has changed. Lovvorn and Baldwin (1996) evaluated waterfowl diets and seasonal changes in food availability in Boundary Bay, British Columbia, which is adjacent to NPL. Wigeon and pintail make up most Boundary Bay's dabbling duck population. Between early September and late November these species meet most of their food energy needs from intertidal habitats dominated by eelgrass. By late November these foods appear depleted and birds shift to foraging in farmlands adjacent to Boundary Bay (Lovvorn and Baldwin 1996).

The depletion of food resources in Boundary Bay led Lovvorn and Baldwin (1996) to suggest that estuarine habitats alone cannot support large populations of dabbling ducks throughout winter. Large numbers of birds could only be sustained if these estuarine habitats were adjacent to farm lands that provide supplemental food resources. To test this prediction the authors analyzed counts of wigeon, pintails, mallards, and green-winged teal from Grays Harbor, WA and from 64 sites throughout Puget Sound between October and March. Twenty of the 64 sites were associated with nearby farmland, which was defined as > 1km^2 of farmland within 6 km of intertidal habitats. These 20 sites accounted for 75% of all wigeon, 94% of all pintail, 93% of all mallards, and 92% of green-winged teal counted between October and March. Duck numbers declined dramatically after November in Grays Harbor, which has limited adjacent farmland (Lovvorn and Baldwin 1996).

Historically, dabbling ducks in NPL would have had access to a series of habitat types that occurred along a gradient of increasing elevation and decreasing salinity. Estuarine habitats dominated by eelgrass were important foraging habitats and remain so today. Landward of these habitats were salt and brackish marshes that were regularly exposed to the tides. Inland of these marshes were wetlands intermittently exposed to tidal flows and dominated by shrub and tree species, although early seral stage marshes were constantly being created by changing river channels and beaver activity. Finally, freshwater wetlands dominated by shrubs and trees would account for most habitat at the higher elevations. More details on NPL's historic and current wetland resources can be found in Appendix I and in the "Conservation Design" section.

Once eelgrass and emergent salt and brackish marsh habitats were depleted it seems unlikely that these other wetland types could have provided substantial food resources for dabbling ducks. Recent food sampling of NPL's salt and brackish marshes suggests that these habitats cannot support high densities of waterfowl for extended periods (see Appendix II). Most wetlands inland of these salt and brackish marshes were dominated by woody vegetation, not seed bearing herbaceous plants favored by dabbling ducks. As a result the carrying capacity of these habitats for dabbling ducks was probably low. During pre-settlement times use of NPL by some species may have peaked in fall and declined in winter as happens today in coastal sites that lack agriculture. Agriculture in NPL includes small grains, vegetables, winter cover crops and pasture grasses that are readily eaten by waterfowl. Mid-winter dabbling duck populations in NPL have increased since the 1970's and half of all birds are now mallards. Mallards in Boundary Bay relied mainly on agricultural foods to meet their energy requirements and made little use of intertidal foods (Lovvorn and Baldwin 1996).

Diving Ducks

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Historic population estimates of diving ducks using NPL are also lacking. Although greater scaup account for most diving ducks found in NPL, the area supports less than 10% of all wintering scaup (greater and lesser) in the PCJV. Scaup feed on both aquatic plants and animals. In marine and estuarine environments mollusks are the principle diet items. In freshwater habitats, seeds, leaves, stems, roots and tubers of aquatic plants are important foods (Bellrose 1980). It is assumed that scaup make no use of agricultural foods and rely entirely on natural habitats.

In NPL, there are more than 100,000 acres of marine and estuarine habitats that potentially support mollusks and other animal food items important to greater scaup. Historic changes in the carrying capacity of these habitats are unknown because for most there are no estimates of historic loss. In addition, there is little known about how the density of important scaup foods may have declined as result of changes in water quality or sediment processes that influence the recruitment and distribution of mollusks and other macro-invertebrates.

Freshwater habitats that are associated with scaup and other diving duck foods are usually classified as palustrine or lacustrine aquatic bed wetlands. Palustrine aquatic bed habitats are absent from NPL, while lacustrine aquatic bed wetlands total just 1100 acres (see Appendix I). It is assumed that most scaup in NPL historically relied on marine and estuarine environments, especially since most freshwater wetlands were dominated by woody vegetation. Any significant loss of diving duck carrying capacity probably resulted from changes in the quantity and or quality of marine and estuarine habitats.

Sea Ducks


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Scoters account for ninety percent of all sea ducks found in NPL (Nysewander et al. 2005). Scoter numbers in NPL have substantially declined since the 1970's and it is reasonable to assume that scoter populations are now below historic levels. Scoters are confined to foraging in estuarine and marine environments, making no use of freshwater wetlands or agricultural habitats. Mollusks and crustaceans are the main food items of scoters, and the marine and estuarine habitats that provide these foods total over 100,000 acres. But, as with diving ducks, historic changes in the carrying capacity of these marine and estuarine habitats to support scoter populations are unknown. Little information is available on how the density of important scoter foods may have declined as result of either changes in water quality or sediment processes that influence the recruitment and distribution of mollusks and crustaceans in NPL.

Wrangel Island Snow Geese


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Snow geese that that historically wintered in NPL relied on estuarine intertidal emergent wetlands (salt and brackish marshes) to meet their nutritional needs (Baranyuk et al. 1999). In recent years geese have become heavily dependent on agricultural foods. This change in foraging ecology has been observed for most populations of snow geese as birds have reduced their use of coastal areas in favor of agricultural habitats (Abraham et al. 2005). The growing number of Wrangel Island birds using NPL is almost certainly related to their increasing use of agricultural food. In the 1960's, up to 90% of all Wrangle Island geese wintered in the Central Valley. Today, 50% of that population now relies on NPL.

Agricultural crops preferred by snow geese in NPL include pasture, waste grain, potatoes, as well as winter cover crops that are planted after the harvest of traditional summer crops to reduce soil erosion and nutrient loss. The planting of cover crops has grown since the 1990's and increasing goose numbers may be related to this practice. The development of sanctuaries may have also improved winter habitat conditions. In 1996, WDFW established the 200 ha Fir Island Reserve and has since planted it with cover crops. Although public habitats such as the Fir Island Reserve are heavily grazed by geese, birds also forage on private lands. At higher numbers, snow geese can cause depredation concerns among landowners, and complaints will likely grow if snow goose numbers increase.

Higher snow goose numbers raise important issues, including the possible degradation of salt and brackish marshes, over 60% which have been lost since settlement. Although geese rely heavily on agricultural habitats they still make use of these estuarine habitats. Intense foraging may further degrade them. Boyd (1995) monitored plots of three-square bulrush in estuarine emergent marshes in both the Fraser River Delta and NPS and concluded that intense grubbing by snow geese had significantly reduced plant biomass.

Pacific Flyway Brant

Brad Otto 2013

Until the early 1950's, as many as half of all Pacific Flyway brant wintered along the coasts of Washington, Oregon, and California. Today, 66% of all birds migrate directly to wintering grounds on the west coasts of Baja California and Mainland Mexico (Dau 1992).
Brant utilizing north Puget Sound wintering habitats in Washington and the Fraser Delta in British Columbia are linked to coastal estuaries with sufficient quantities of eelgrass (*Zostera* spp.) and sea lettuce (*Ulva* spp.), as well as adequate haul-out and grit access sites. Numbers of brant utilizing migration and wintering habitats in Washington have been strongly related to the abundance of eelgrass in these habitats (Wilson and Atkinson 1995, Ward et al. 1999, Moore et al. 2004). The Padilla Bay National Estuarine Research Reserve completed an extensive inventory of eelgrass meadows in Padilla, Samish, and Fidalgo Bays in 1990 and another was completed by the Washington Department of Natural Resources in 1996. However, no trends were evident during this period (T. Mumford pers. comm.). The total area occupied by eelgrass in the Puget Sound has remained relatively stable since 2000, but declines have occurred at smaller scales (Gaeckle et al. 2009).

Upper intertidal areas in north Puget Sound have been invaded by an introduced seagrass (*Zostera Japonica*), which may have increased the food base for waterfowl (Baldwin and Lovvorn 1994). Sea lettuce also appears to be increasing in North Puget Sound (T. Mumford pers. comm.) Maintaining or increasing marine and estuarine habitats is especially important to meeting population objectives for these birds.

Swans

Populations of both trumpeter and tundra swans have steadily increased in the Pacific Flyway over the past 40 to 50 years. In the early 1970's less than 100 trumpeter swans were reported in NPL (Bellrose 1980). Today the population exceeds 6500 birds and the number of swans now wintering in NPL may exceed pre-settlement numbers. In the absence of agricultural foods swans typically feed on the leaves, stems, and tubers of aquatic plants (Bellrose 1980). In NPL these foods usually occur in freshwater habitats that are classified as palustrine or lacustrine aquatic bed wetlands. Palustrine aquatic bed habitats are absent from NPL, while lacustrine aquatic bed wetlands total just 1100 acres (see Appendix I). Even if these wetland classes were more abundant prior to settlement it's unlikely that they could have provided the food resources that are now available in agricultural habitats. Observations of foraging swans in NPL indicate that birds acquire almost all their food from agricultural sources, although palustrine and lacustrine wetlands provide important roost sites.

Waterbirds

Waterbirds are a diverse group of species that depend on aquatic habitats for some part of their life cycle (Kushlan et al. 2002). Forty-seven species of waterbirds are found in the NPL, with most use occurring between September and May. Waterbirds in NPL rely mainly on intertidal habitats and freshwater wetlands, although some use of agricultural lands and open fields does occur (Table 1). While there are no estimates of the number of waterbirds that historically relied on NPL, many of the habitats used by this bird group have suffered very high loss rates (Appendix I).

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Table 1. Waterbird species found in North Puget Lowlands and their general habitat use. Occurrence defined by species use code where M = migration, W = wintering and B = breeding.

Species	Occurrence*	Habitat Use
Red-throated Loon	m, ***W***	Protected bays and large estuaries; usually found within a mile of shore near extensive mudflats
Pacific Loon	m, ***W***	Inland marine waters; usually found farther from shore than other loon species
Common Loon	b***, M, W***	Inland marine waters; also found breeding and wintering on freshwater lakes
Yellow-billed Loon	w	Rare in winter on inland marine waters
Horned Grebe	***W***	Coastal bays and exposed shores; occasionally winter on freshwater lakes
Eared Grebe	m, w	Open freshwater lakes and occasionally protected salt water bays
Red-necked Grebe	***W***	Protected bays, marshes, and coastal areas; occasionally in open marine waters
Pied-billed Grebe	***B, M, W***	Freshwater wetlands with marshy, emergent vegetation and calm, open fresh and salt water; winter populations contain both resident and northern-breeding migratory individuals
Western Grebe	b***, M, W***	Large numbers winter together on saltwater bays; few in coastal areas during summer
Clark's Grebe	b, m, w	Freshwater lakes and saltwater bays; usually found farther from shore than Western Grebes
American White Pelican	b, m, w	Rare on freshwater lakes and near the coast year-round
Brown Pelican	m	Shallow marine areas such as bays, offshore islands, spits, breakwaters, and open sandy beaches
Brandt's Cormorant	b, ***M, W***	Salt or brackish water usually along rocky shorelines or coastal islands
Pelagic Cormorant	***B, M, W***	Inland marine waters, usually fairly close to shore; breed on small, offshore islands and rocky cliffs with deep water at the base
Double-crested Cormorant	***B, M, W***	Forage in ponds, lakes, slow-moving rivers, estuaries, and open coastlines; breeding colonies located on small rocky or sandy islands, or exposed tops of offshore rocks
American Bittern	b, w	Freshwater marshes and wet meadows with heavy cattail growth and open water
Great Blue Heron	***B, M, W***	Forage in slow-moving or calm fresh, brackish, or salt water; nesting colonies found in forest, on islands, or near extensive mudflats
Great Egret	b, ***M***, w	Freshwater wetlands; usually forage in open areas of lakes, large marshes, and along large rivers
Cattle Egret	w	Open agricultural country; breeds in freshwater marshes or on islands in large colonies
Black-crowned Night Heron	b, m, w	Feed in freshwater and saltwater wetlands, forested swamps, and riparian areas; breed in freshwater habitat
Virginia Rail	***B, M, W***	Found primarily in freshwater marshes and less often in salt/brackish marshes; associated with cattails
Sora	b, m, w	Cattail marshes at lower elevations to moist sedge meadows in cooler, higher areas; also occur in brackish marshes, especially in winter and during migration
American Coot	b***, M, W***	Found in large freshwater ponds, lakes, and slow-moving rivers; nest in tall marsh vegetation in shallow water; occasionally found in salt marshes and protected coastal bays
Sandhill Crane	***M, W***	Forage in grain fields, pasture, and wet meadows; also found in river valleys during migration
Bonaparte's Gull	***M,*** w	Winter in coastal areas, lakes, sewage ponds, estuaries, and open ocean; found during migration in lowland saltwater, sandy-shore, and freshwater habitats
Little Gull	m	Along coasts in protected shallow estuaries, mudflats, and beaches, and nearby fresh water lakes
Franklin's Gull	m	Winter in coastal areas, lakes, sewage ponds, estuaries, and open ocean; found during migration in lowland saltwater, beach, and freshwater habitats

Species	Occurrence*	Habitat Use
Mew Gull	***M, W***	Inhabits coastal waters: estuaries, Vasiliy Baranyuk © 2013 river mouths, and freshwater ponds close to the shore; not often found at landfills
Ring-billed Gull	b***, M, W***	Found near natural fresh or inland salt water; often take advantage of foraging opportunities in developed areas such as parking lots, restaurants, landfills, and agricultural areas
California Gull	b, ***M***, w	Common during fall migration in offshore and coastal habitats across the NPL region
Herring Gull	m, w	Found on open salt or fresh water, but also common on beaches, mudflats, plowed fields, marshes, docks, commercial fishing areas, and landfills
Thayer's Gull	m, ***W***	Found around bodies of water near the coast, including estuaries and protected bays; also found far offshore, on freshwater ponds, and at landfills near the coast
Glaucous Gull	w	Found at many natural and human-modified coastal habitats: landfills, fish-processing plants, harbors, mud flats, sewage lagoons, flooded fields, and fish-spawning areas
Glaucous-winged Gull	***B, M, W***	Commonly found in almost all coastal habitats, and in lakes, agricultural fields, cities, and landfills; breeding colonies at Colville, Smith, and Minor Islands in San Juan County
Western Gull	b, m, w	Found at estuaries, beaches, fields, landfills, and city waterfronts year-round
Heerman's Gull	***M,*** w	Uses a variety of coastal habitats, including rocky shores, bays, small offshore islands, kelp beds, sandy beaches, and estuaries; not often found at landfills or lakes
Black Tern	b, m	Uses large lakes and shorelines during migration
Caspian Tern	***B,*** m	Nest on dredge-spoil islands; non-breeders can be found in bays and estuaries along the coast during the summer
Common Tern	m	During migration, uses coastal areas in saltwater and sandy-shore habitats
Arctic Tern	b	Nested on Jetty Island and then in a gravel parking lot in Snohomish County from 1977-1995 but habitat was subsequently developed; not often seen near shore otherwise
Common Murre	***B, M, W***	Found both in open ocean and in large bays: closer to rocky shorelines during the breeding season, and in deep-water inland marine habitats during the winter
Pigeon Guillemot	***B, M, W***	Nest along the salt-water coastlines of the NPL in practically every small island or bay; more common and widespread in inland marine habitats in the winter
Marbled Murrelet	***B, M, W***	Calm, shallow, coastal waters and bays; breed inland, up to 45 miles from shore in mature, wet forest
Ancient Murrelet	m	Found mostly on cold-water seas, foraging over the edge of the continental shelf; also found closer to shore, especially in areas where tidal currents bring food up to the surface
Rhinocerous Auklet	***B,*** m, w	Common around islands and inland marine waters; feed close to shore, especially where tidal currents near islands create upwellings and concentrations of food
Tufted Puffin	b	Seen only occasionally near land, more open-water areas than other alcids

* Capitalized, Bold, Italics - species occurs regularly in the region, and management in region is relatively more important than other regions where it occurs; Capitalized - species occurs regularly, and in large enough numbers to warrant management; Lower Case - species occurs rarely to regularly, but not in large enough numbers to warrant management (exclusive of Threatened & Endangered Species).

Shorebirds

Four species of shorebirds occasionally to regularly breed in NPL, and over thirty other species use the region during migration and winter (Paulson 1993, Drut and Buchanan 2000, Buchanan 2004; Table 2).

Shorebirds in NPL use a variety of habitats including sand beaches, rocky shorelines, intertidal mud-flats, salt and brackish marshes, the shorelines of freshwater wetlands, and shallowly flooded agricultural lands. Shorebird numbers are usually highest between July and early May, although failed or non-breeding adult shorebirds may be present in small numbers during May and June.

Evenson and Buchanan (1997) surveyed sixty-six sites in NPL that were thought to be important for shorebirds. Although shorebird use of these sites varied between species, years, and seasons, certain species like Western Sandpipers and Dunlin were abundant across surveys and made up a large proportion of the shorebirds observed in NPL (Table 3). Unfortunately, there are no estimates of the number of shorebirds that historically relied on NPL.

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Table 2. Shorebird species found in North Puget Lowlands. Occurrence defined by species use code where M = migration, W = wintering and B = breeding.

Species		Occurrence*
Black-Bellied Plover	*Pluvialis squatarola*	**M**, W
American Golden-Plover	*Pluvialis dominica*	m
Pacific Golden-Plover	*Pluvialis fulva*	M
Semipalmated Plover	*Charadrius semipalmatus*	**M**, w
Killdeer	*Charadrius vociferous*	**M, W**
Black Oystercatcher	*Haemotopus bachami*	M, **W, B**
Greater Yellowlegs	*Tringa melanoleuca*	**M**, W
Lesser Yellowlegs	*Tringa flavipes*	m
Solitary Sandpiper	*Tringa solitaria*	m
Wandering Tattler	*Heteroscelus incanus*	M
Spotted Sandpiper	*Activism macularia*	m, w, b
Whimbrel	*Numenius phaeopus*	**M**, w
Long-Billed Curlew	*Numenius americanus*	M, w
Marbled Godwit	*Limosa fedoa*	M, w
Ruddy Turnstone	*Arenaria interpres*	M, w
Black Turnstone	*Arenaria melanocephala*	M, **W**
Surfbird	*Aphriza virgata*	M, **W**
Red Knot	*Calidris canutus*	**M**
Sanderling	*Calidris alba*	**M,W**
Semipalmated Sandpiper	*Calidris pusilla*	m
Western Sandpiper	*Calidris mauri*	**M**, w
Least Sandpiper	*Calidris minutilla*	M, w
Baird’s Sandpiper	*Calidris bairdii*	m
Pectoral Sandpiper	*Calidris melanotos*	m
Sharp-tailed Sandpiper	*Calidris acuminate*	m
Rock Sandpiper	*Calidris ptilocnemis*	m, w
Dunlin	*Calidris alpina*	**M, W**
Stilt Sandpiper	*Calidris himanotopus*	m
Buff-Breasted Sandpiper	*Tryngites subruficollis*	m
Ruff	*Pilomachus pugnax*	m
Short-billed Dowitcher	*Limnodromus griseus*	**M**
Long-billed Dowitcher	*Limnodromus scolopaceus*	**M**, w
Wilson’s Snipe	*Gallinago delicate*	m, **W**, b
Wilson’s Phalarope	*Phalaropus tricolor*	m, b
Red-necked Phalarope	*Phalaropus lobatus*	**M**
Red Phalarope	*Phalaropus fulicaria*	**M**, w

* Capitalized, Bold, Italics - species occurs regularly in the region, and management in region is relatively more important than other regions where it occurs; Capitalized - species occurs regularly, and in large enough numbers to warrant management; Lower Case - species occurs rarely to regularly, but not in large enough numbers to warrant management (exclusive of Threatened & Endangered Species)

Table 3. North American population estimates and peak counts for shorebirds at estuaries in North Puget Lowlands.

Common Name	NA Population[1]	Mean Seasonal High Counts[2] Winter	pring	Fall
Black-bellied Plover	50,000	756	549	661
American Golden-Plover	200,000	n/a	n/a	n/a
Pacific Golden-Plover	35,000-50,000	n/a	n/a	n/a
Semipalmated Plover	150,000	1	61	95
Killdeer	1,000,000	294	40	188
Black Oystercatcher	10,000	11	17	1
Greater Yellowlegs	100,000	49	135	112
Lesser Yellowlegs	400,000	2	4	32
Solitary Sandpiper	150,000	0	1	1
Wandering Tattler	10,000-25,000	0	1	1
Spotted Sandpiper	150,000	3	0	10
Whimbrel	66,000	2	400	6
Long-billed Curlew	55,000-123,500	0	1	0
Marbled Godwit	2,000	1	2	1
Ruddy Turnstone	20,000	7	3	18
Black Turnstone	95,000	260	82	62
Surfbird	70,000	28	0	3
Red Knot	20,000	0	1	3
Sanderling	300,000	752	207	263
Semipalmated Sandpiper	2,000,000	0	0	1
Western Sandpiper	3,500,000	1,082	53,717	31,961
Least Sandpiper	700,000	38	300	1628
Baird's Sandpiper	300,000	0	0	3
Pectoral Sandpiper	500,000	0	0	1
Rock Sandpiper	50,000	6	1	1
Dunlin	550,000	64,697	51,214	43
Stilt Sandpiper	820,000	0	0	1
Buff-breasted Sandpiper	30,000	0	0	1
Dowitcher sp.	475,000	138	286	274
Wilson's Snipe	2,000,000	25	1	1
Red-necked Phalarope	2,500,000	4	0	138
Red Phalarope	1,250,000	6	0	0

[1]Information from Morrison et al. (2006), [2] Counts from Evenson and Buchanan (1997); data are seasonal peak counts averaged across all years of study (winter: 1990-1996; spring: 1991, 1993-1994; fall: 1991-1993), n/a: not available

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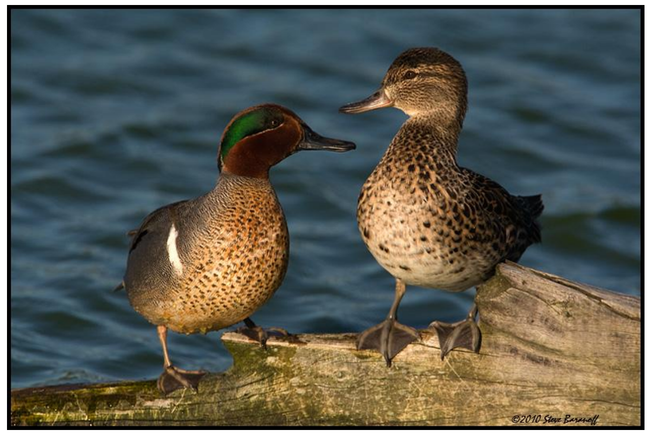
Bird Population Objectives and Priority Species

Joint Ventures have been encouraged to develop bird population objectives and to identify species of management concern. The JV recognizes seven wetland dependent bird groups based on habitat use and foraging ecology; 1) dabbling ducks, 2) diving ducks, 3) sea ducks, 4) geese, 5) swans, 6) shorebirds, and 7) waterbirds. Population objectives were established for all species in a bird group if possible. For some bird groups like dabbling ducks, these species objectives were combined to form an overall population objective. The JV also identified priority species based on the following;
1) status as a U.S. Fish and Wildlife Service (USFWS) bird species of management concern, and 2) the relative abundance of a species in its bird group (e.g. mallards make up over 50% of the dabbling duck objective). The biological requirements of these priority species are emphasized in the NPL plan.

This plan addresses the biological needs of waterfowl during the non-breeding period. The PCJV defines the non-breeding period as September through May, though it may be shorter for some waterfowl groups or species. Monthly population objectives were established for each waterfowl species/group during the non-breeding period if possible. For shorebirds and waterbirds, the plan considers biological needs for both the breeding and non-breeding periods. The objectives are intended to apply to habitat rather than population or harvest management programs. For example, a dabbling duck population objective of 100,000 birds means that the PCJV strives to provide wintering habitat capable of supporting 100,000 dabbling ducks.

Dabbling Ducks

In 1986 the NAWMP developed population objectives for North American duck species based on environmental conditions and breeding waterfowl numbers from 1970-1979. Waterfowl populations in the 1970's met the demands of both consumptive and non-consumptive users and provided a basis for future conservation efforts. Population objectives from the NAWMP have been "stepped down" to Joint Ventures that support migrating and wintering waterfowl. By combining information from the mid-winter waterfowl survey (MWS) with estimates of waterfowl harvest and mortality, population objectives for the mid-winter period (early January) were established for all counties in the U.S. Counties were then combined to develop Joint Venture population objectives (Koneff 2003).



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To account for possible changes in the distribution of migrating and wintering waterfowl since the 1970's, NAWMP population objectives have been stepped down to each Joint Venture based on mid-winter counts and harvest data from both the 1970's and the 1990's. Although this resulted in little change for some Joint Ventures, dabbling duck population objectives for the PCJV increased from 1,056,000 to 1,519,000 birds when 1990's mid-winter and harvest data were used. Reasons for an increase in wintering ducks in the PCJV are unclear but may be related to growing breeding populations in Alaska. For planning purposes dabbling duck objectives from 1990's data were used.

The NAWMP mid-winter objective for dabbling ducks in the NPL Focus Area is presented in Table 4. Mallards (*Anas platyrhynchos*) account for 57% of this objective, while American wigeon (*Anas Americana*) account for

25%. Northern pintail (*Anas acuta*) total 16% of the mid-winter objective, while green-winged teal (*Anas crecca*), gadwall (*Anas strepera*), and northern shovelers (*Anas clypeata*) make up the remaining 2%. Dabbling ducks are not uniformly distributed in NPL. Mid-winter population objectives stepped down to each county indicate that 83% of all dabbling ducks occur in Skagit and Snohomish Counties, while only 1% of all birds occur in San Juan County (Table 5). In general the distribution of dabbling ducks reflects the distribution of historic and existing wetlands in NPL.

Table 4. Mid-winter population objectives for waterfowl in North Puget Lowlands. Mid-winter population objectives do not necessarily correspond to peak population objectives. Data not available for group objectives of sea ducks, geese and swans.

Bird Group and Priority Species	Mid Winter Population Objective	Status: U.S. Fish & Wildlife Service	Status: Continental Population
Dabbling Ducks	388,121[a]		
Mallard	220,344[a]	GBBDC	No trend [f]
American wigeon	97,565 [a]	GBBDC	Decreasing [f]
Northern pintail	63,916 [a]	GBBDC	Decreasing [f]
Diving Ducks	49,325 [a]		
Greater scaup	41,401 [a]	GBBDC	Increasing [f]
Sea Ducks			
Scoter[b]	125,840	GBBDC	Decreasing
Geese			
Brant	20,000 [c]	GBBDC	No Trend [g]
Wrangel Island Snow Geese	74,000 [d]	GBADC	Increasing [g]
Swans			
Trumpeter Swan	6,758[e]	Not Listed	No Trend [g]
Tundra Swan	2,253[e]	Not Listed	No Trend [g]

[a] Derived from the North American Waterfowl Management Plan, [b] Includes all three scoter species but predominately surf and white-winged, [c] Data from Pacific Flyway Management Plan for Pacific Brant, [d] Data from Pacific Flyway Management Plan for the Wrangel Island Population of Lesser Snow Geese, [f] Population trend 1970-2006, [g] Population trend 1997-2006, GBBDC – Game Birds Below Desired Conditions, GBADC – Game Birds Above Desired Conditions

Mallards, northern pintail, and wigeon have all been designated as birds of Birds of Management Concern by the USFWS and are further classified as Game Birds Below Desired Condition. As a result, the PCJV recognizes mallards, wigeon, and northern pintail as priority dabbling duck species based on their FWS status and their contribution to the dabbling duck mid–winter goal. Although selecting priority species based on mid-winter abundance can overlook dabbling ducks that reach peak numbers during fall or spring, mallards, wigeon, and pintail remain the predominate species in NPL throughout the non-breeding period (Kraege 2012). For the period 1970 to 2006, continental mallard populations showed no significant trend while populations of wigeon and northern pintail declined (Table 4). Continental populations of non-priority species including green-winged teal, gadwall, and northern shovelers, all significantly increased during this time (NAWMP Steering Committee 2007).

Table 5. Mid-winter dabbling duck population objectives for North Puget Lowland counties.

County	Objective: Population	Objective: % of NPL
Island	22,965	6
San Juan	3,008	1
Skagit	140,701	36
Snohomish	180,952	47
Whatcom	40,494	10
Total	388,121	100

Although population objectives stepped down from the NAWMP only apply to the mid-winter period, dabbling ducks rely on NPL from September through April. To establish monthly population objectives from September to April, the PCJV combined information on migration chronology with the NAWMP mid-winter objective (Petrie et al. 2011). Migration chronology was partly determined from aerial surveys conducted monthly between October and January by the Washington Department of Fish and Wildlife. These surveys indicate that peak dabbler numbers usually occur in December (Figure 4).

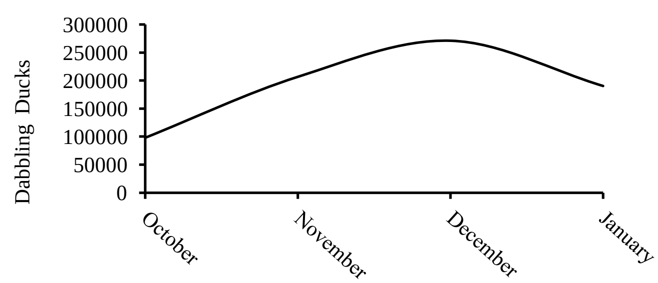

Figure 4. Average monthly counts of dabbling ducks in North Puget Lowlands from 1992 – 2005.

Monthly population objectives were established by adjusting the NAWMP objective to reflect migration chronology. For example, the NAWMP mid-winter or January objective for dabbling ducks is 388,121 birds. Surveys indicate that dabbling duck populations in December average 142 % of January numbers. Thus, the dabbler population objective for December is 388,121 *1.42 or 551,132 ducks. Dabbling duck numbers in October average 52% of January numbers and the population objective for October is 0.52 * 388,121 or 201,823 birds.

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Although aerial surveys of waterfowl are conducted from October through January in NPL, dabbling duck objectives must also be established for September, February, March, and April. These surveys indicate that dabbling ducks increase in a linear manner between October and November and that duck populations in October average 50% of November populations (Figure 4). A similar rate of increase was assumed between September and October, so that the September objective is set at half the October goal. To establish population objectives for February, March, and April, wigeon and pintails that were radio-marked in the adjacent Fraser River Delta in 2004/2005 and 2005/2006 were used. These marked birds provide a measure of turnover rates or the % of birds present in January that depart the region between February and April. Ninety five percent of all birds present in January were located in February after birds that had died were accounted for (D. Buffet unpubl. data). Thus, the dabbling duck population for February is 368,175 birds or 95% of the 388,121 January objective.

Population objectives for March and April were established using the same approach, with 81% and 57% of marked birds located in March and April respectively (Table 6). Unfortunately, the use of marked birds to establish population objectives from February to April does not account for immigration. Large numbers of birds that winter south of NPL may migrate into the area in March and April, and radio-marked birds present in NPL in January do not measure the contribution that spring migrants make to dabbling duck populations in these months.

Table 6. Monthly dabbling duck population objectives for North Puget Lowlands

Month	Dabbling Duck Population Objectives
September	100,911
October	201,823
November	423,052
December	551,132
January	388,121
February	368,715
March	314,378
April	221,229

Diving Ducks


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Mid-winter population objectives for diving ducks have also been stepped down from the NAWMP and are based on breeding waterfowl numbers from 1970-1979. To account for possible changes in the distribution of diving ducks since the 1970's, NAWMP population objectives have been stepped down based on mid-winter counts and harvest data from both the 1970's and the 1990's as was done for dabbling ducks. Diving duck population objectives for the entire PCJV increased from 300,000 to 482,000 birds when 1990's mid-winter and harvest data were used (Koneff 2003). Although diving duck population objectives for the PCJV increased when 1990's data were used, diving duck objectives for NPL actually declined from 49,000 to 27,000 birds. Reasons for these divergent trends are unclear but the larger 49,000 bird figure was used as a population objective (Table 4**)**. Scaup account for nearly 84% of this objective with most being greater scaup (*Aythya marila*). Ruddy ducks (*Oxyura jamaicensis*) account for another 10% of the mid-winter objective, while ring-necked ducks, redheads, and canvasbacks make up the remaining 6%.

Diving ducks are not uniformly distributed in NPL. Mid-winter population objectives stepped down to the county level indicate that 73% of all dabbling ducks occur in Skagit and Snohomish Counties, while the remaining 27% occur in San Juan and Whatcom Counties (Table 7). Greater scaup have been designated as a Bird of Management Concern by the FWS and are further classified as a Game Bird Below Desired Condition, and the PCJV recognizes greater scaup as a priority species based on its FWS status and their contribution to the diving duck goal. While other diving ducks have been given similar FWS status, they are not considered priority species due to their low numbers in NPL. Moreover, continental populations of non-priority diving duck species in NPL increased or were stable between 1970 and 2006 (NAWMP Steering Committee 2007).

Diving duck population objectives stepped down from the NAWMP only apply to the mid-winter period, although diving ducks rely on NPL from September to April. To establish monthly population objectives, information on migration chronology was combined with the NAWMP mid-winter objective as described for dabbling ducks. Since no migration data is available for diving ducks, diving duck migration chronology was assumed to be similar to dabbling ducks. Monthly diving duck population objectives are presented in Table 8**.**

Table 7. Mid-winter diving duck objectives for North Puget Lowlands counties.

	Objectives	
County	**Population**	**% of NPL**
Island	0	0
San Juan	4,961	10
Skagit	14,663	30
Snohomish	21,143	43
Whatcom	8,559	17
Total	49,325	100

Table 8. Monthly diving duck population objectives for North Puget Lowlands.

Month	Diving Duck Population Objective
September	12,825
October	25,649
November	53,764
December	70,535
January	49,325
February	46,859
March	39,953
April	28,115

Sea Ducks

Scoter

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NAWMP populations objectives for dabbling ducks and diving ducks are based on breeding waterfowl numbers from 1970-1979. However, population estimates from the 1970's are not available for most sea duck species so establishing sea duck population objectives that are connected to the NAWMP is challenging.

Mid-winter waterfowl surveys indicate that 90% of all sea ducks in Puget Sound are scoters (Nyswander et al. 2005). While all three scoter species occur in Puget Sound, the majority of these birds are surf (*Melanitta perspicillata*) and white-winged scoters (*Melanitta fusca*; Bellrose 1980). Scoters are difficult to distinguish during aerial surveys. However, combined counts of white-winged, surf, and black scoters (*Melanitta perspicillata*) estimated from the North American Waterfowl Breeding and Habitat Survey (USFWS 2013) indicate that scoters as a whole have declined by 50% since the 1950's. The greatest decline has occurred in the northern boreal forest regions of western Canada and Alaska, although the reasons are unknown (SDJV 2013). All three scoter species have been designated as a Bird of Management Concern by the FWS and are further classified as Game Birds Below Desired Conditions (Table 4). Accordingly, the PCJV recognizes surf and white-winged scoters as a priority species based on their FWS status and their contribution the overall scoter population in NPL.

In 1992, WDFW began standardized aerial surveys of scoters in Puget Sound to provide a population estimate since the MWS only provides a population index. Puget Sound lies in the western Washington survey unit of the MWS and most scoters observed in this unit occur in Puget Sound (Trost et al. 2007). Between 1992 and 2005, WDFW scoter population estimates for Puget Sound corresponded well with the number of scoters observed in the western Washington survey unit. This allowed the PCJV to develop a predictive equation that estimated scoter populations in Puget Sound based on the number of scoters counted in the western Washington unit. Mid-winter survey counts for western Washington during the 1970's were entered into this predictive equation to generate annual population estimates for Puget Sound between 1970 and 1979. These population estimates were averaged to provide a mid-winter population objective of 242,000 scoters for Puget Sound. The mid-winter population of scoters in Puget Sound is now estimated at about 60,000 birds, but this estimate is not corrected for visibility bias (Don Kraege unpubl. data).

The mid-winter scoter objective of 242,000 birds needs to be subdivided between NPL and South Puget Lowlands. Scoter population estimates for Puget Sound can be broken down by county. Between 1997 and 2006, NPL counties hosted 52% of the Puget Sound scoter population. As a result, the PCJV adopted a mid-winter scoter population objective of 125,840 birds for NPL (Table 4).

Geese

Because many North American goose populations have significantly increased from the 1970's or have undergone major changes in wintering distribution, Joint Ventures have been advised to use more recent information when establishing goose population objectives (M. Koneff pers. comm.). In NPL, the PCJV recognizes two priority species of geese; 1) Pacific Flyway brant (*Branta bernicla*), and 2) Wrangel Island snow geese (*Chen caerulescens*). While both species have been identifies as Birds of Management Concern, Wrangel Island snow geese are now considered to be above desired condition (Table 4). While small numbers of Canada geese (*Branta canadensis*) occur in NPL they are not included in the plan.

Pacific Flyway Brant

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The PCJV's review of Pacific Flyway brant relies heavily on the Pacific Flyway Management Plan for Brant (Pacific Flyway Council in prep). Pacific Flyway brant include brant breeding in Alaska, the western Canadian arctic, and wintering primarily along the Pacific Coast from Alaska to Mexico. Pacific Flyway brant are composed of black brant and western high arctic brant (WHA). Black brant are the most common and breed primarily in Alaska, the low Arctic of western Canada, and northeastern Russia (Palmer 1976, Banikov et al. 1983). WHA brant breed on the Parry Islands in Northwest Territories / Nunavut and display lighter breast plumage characteristics compared to black brant.

From the mid 1930's through the early 1950's, as many as half of all Pacific Flyway brant may have wintered along the coasts of Washington, Oregon, and California. By the 1960's brant had shifted their distribution from the coastal U.S. to Mexico. Today, up to 66% of all birds migrate directly to wintering areas on the west coasts of Baja California and Mainland Mexico (Dau 1992, Pacific Flyway Council in prep).

The Pacific Flyway council has established a mid-winter objective of 162,000 brant. This overall population objective has been stepped down to specific wintering areas, including NPL, which has a midwinter population objective of 20,000 birds (Table 4). The objective includes sub-objectives of 8,000 birds for Birch and Bellingham bays in Whatcom County, and 12,000 birds for Samish, Padilla, and Fidalgo Bays in Skagit County (Pacific Flyway Council in prep).

Pacific Flyway brant numbers increased between 2001 and 2010, but the mid-winter population objective of 162,000 birds was not met in any of those years. During this period mid-winter counts of brant averaged 135,000. The 2004 – 2013 MWS averages for Skagit County (9,800) and Whatcom County (3,600) were also below the Pacific Flyway plan objectives.

In 2005, twenty male WHA brant were marked with satellite transmitters on their Canadian breeding grounds. Seventeen of these birds migrated to NPL, the first bird arriving on Nov 26 and the last bird on December 15. The average date of arrival was December 3 with a standard deviation of 5.9 days (Boyd et al. unpubl. data). These marked birds suggest that most geese arrive in early December and that migration into NPL occurs over a short time period. Radio-marked WHA geese began leaving Puget Sound in May, the average date of departure being May 27 (SD 9.6 days; Boyd et al. unpubl. data). Thus, most WHA brant arrive in Puget Sound in early December and depart in late May. It was assumed that bird numbers are constant from December 1 through the end of May, so the mid-winter population objective of 12,000 birds for Samish, Padilla, and Fidalgo bays was applied to all months (Table 9).

Table 9. Monthly population objectives for western high arctic (WHA) and black brant in North Puget Lowlands.

Month	WHA Population Objective	Black Brant Population Objective	Total Black Brant Population Objective
November	0	5,600	5,600
December	12,000	6,160	18,160
January	12,000	8,000	20,000
February	12,000	8,000	20,000
March	12,000	12,000	24,000
April	12,000	21,440	33,440
May	12,000	6,400	18,400

Information on the migration chronology of black brant in Birch and Lummi bays is lacking. Although monthly surveys have been done in NPL, it is difficult to separate counts of black and WHA brant. Monthly population objectives for black brant were established using information on migration chronology from Willapa Bay, where the entire population is composed of black brant (D.

Kraege pers. comm.). The black brant objective for Birch and Lummi bays increases from 5,600 birds in November to the mid-winter objective of 8,000 birds by January. The 8,000 bird objective remains unchanged through February and increases to 12,000 birds in March as brant wintering south of NPL begin spring migration. The peak population objective of 21,440 birds occurs in April and corresponds to the peak of spring migration (Hagmeier et al. 2007). April counts of brant in NPL averaged over 30,000 birds in the 1970's, after which bi-weekly April surveys were discontinued. The combined April population objective for black and WHA brant is 33,440 birds (Table 9).

Wrangel Island Snow Geese

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Snow geese that winter in NPL are part of a larger population of birds that include geese wintering in the adjacent Fraser River Delta (FRD) – all of which breed on Wrangel Island off the northeastern coast of Siberia. Geese begin leaving Wrangel Island in late August with most birds wintering in NPL / FRD or the Central Valley of California. The wintering distribution of Wrangel Island geese has undergone a significant shift north. In the 1960's, up to 90% of the population wintered in the Central Valley. By the late 1980's over half the population was found in NPL / FRD, and by 2000 60% of all Wrangel Island snow geese wintered in NPL / FRD (Boyd and Cooke 2000). However, the NPL population has declined recently and currently accounts for about 50% of the total population.

The Pacific Flyway Council has established a spring population objective of 120,000 snow geese for Wrangel Island, while trying to maintain the current wintering distribution of Wrangel Island birds between NPL / FRD and the Central Valley (Pacific Flyway Counsel 2006). Since 1998, the spring population has averaged a 5% annual growth rate and in 2004 and 2005 117,500 birds were counted on Wrangle Island. During this two year period mid-winter counts of snow geese in NPL / FRD averaged 74,000 birds - a figure that was adopted as a mid-winter population objective because it corresponds to a period when the Wrangle Island spring population was near goal (Table 4).

To develop monthly population objectives for snow geese between October and April, the mid-winter objective was combined with information on migration chronology as described for dabbling ducks. Migration chronology was determined from Boyd (1995**).** Although snow goose numbers increase through October, by early November bird numbers stabilize and remain generally constant until the end of March. Goose numbers then decline in April as spring migration begins (Boyd 1995). Because snow goose numbers in NPL are essentially flat between November 1 and March 30, the mid-winter population objective of 74,000 birds was applied across this five month period. However, establishing monthly population objectives is complicated by a temporal shift in bird distribution between NPL and the FRD. Birds are roughly split between the two regions from October through December but by January the majority of geese occur in NPL. As a result, the monthly distribution of birds among NPL and the FRD was used to adjust monthly population objectives for NPS (Table 10). For example, because an average of 55% of all geese occurs in NPL during December the December population objective for NPL is 40,700 (74,000 * 0.55). The monthly distribution of geese between NPL and FRD was determined from Boyd (1995).

Table10. Monthly population objectives for Wrangel Island snow geese in North Puget Lowlands.

Month	Population Objective
October	19,366
November	30,340
December	40,700
January	62,900
February	71,040
March	62,160
April	25,974

Swans

Trumpeter & Tundra Swans

Both trumpeter (*Cygnus buccinator*) and tundra swans (*Cygnus* sp.) occur in NPL during the non-breeding period. For management purposes, trumpeter swans are divided into three populations; 1) Pacific Coast, 2) Rocky Mountain, and 3) Interior Population (Pacific Flyway Council 2006). Trumpeter swans that winter in NPL are part of the Pacific Coast Population (PCP) and breed mostly in Alaska. The Pacific Flyway council has established a PCP breeding objective of 25,000 birds.

PCP trumpeter swans have shown a consistent increase since breeding ground surveys were begun in 1968. A comprehensive survey of their Alaska nesting grounds in 2005 estimated nearly 24,000 trumpeter swans, with another 1200 birds detected from aerial surveys in the Yukon Territory and British Columbia. These surveys indicate that the population is currently at or near objective. Although PCP trumpeter swans winter from Cordova, Alaska to northwest Oregon, most birds winter in coastal and interior areas of British Columbia and western Washington.

Tundra swans that winter in NPL belong to the Western Population (WP) of tundra swans. The population is monitored using the Pacific Flyway Midwinter Waterfowl Survey, which provides an index of swan numbers. The winter index for WP tundra swans doubled during the 1950's, increased by 50% in the 1970's and 1980's, and continued to increase through the 1990's (Pacific Flyway Council 2006). The Pacific Flyway Council has established a mid-winter population index of 60,000 birds, an objective that has been exceeded in every year since 1992. The WP winter index averaged over 100,000 birds from 2005 to 2007. Although tundra swans winter from southeast Alaska to San Francisco Bay, most birds winter in the Central Valley of California.

Ground counts of trumpeter and tundra swans wintering in NPL began in 2005. Counts are conducted in mid to late January depending on the year and are completed over a two to three day period. County-wide surveys are completed in one day to reduce the likelihood of double counting (J. Bohannon pers. com.). Swans were counted in all years between 2005 and 2008 in Whatcom, Skagit, and Snohomish counties, while swans in San Juan County were surveyed in 2006, 2007, and 2008. Both trumpeter and tundra swans appear to be at or near population objectives established by the Pacific Flyway Council, and the PCJV assumes that ground counts of swans between 2005 and 2008 provide an estimate of the number of swans using NPS when trumpeter and tundra swan populations are at objective levels. The average number of swans counted in each county between 2005 and 2008 was combined to provide a January or mid-winter population objective of 9011 birds for NPL (Table 4). On average, 75% of all swans present in NPL are trumpeter swans and nearly 70% of all swans occur in Skagit County.

Swans are present in NPL from late October until early April (J.Bohannon pers. com.). The PCJV used swan counts from Whatcom County between November 1, 2004 and January 29, 2005 to establish monthly population objectives for the entire NPL, as these counts were assumed to reflect swan migration across the region. Monthly population objectives between November 1 and February 1 were established by combining information on swan migration chronology with the January population objective, as described for dabbling ducks. Swan counts from Whatcom County indicate that bird numbers peak in late November and remain stable through January. Swan numbers begin to decline in early March with most birds gone by the end of the first week of April (J. Bohannon pers. com.). As a result, the PCJV assumed that swan numbers decline in a linear manner between March 1 and April 1 (Table 11**)**.

Table 11. Monthly population objectives for swans in North Puget Lowlands.

Month	Population Objective
November	4,441
December	9,011
January	9,011
February	9,011
March	4,506

Shorebirds

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The U.S. Shorebird Conservation Plan (USSCP) has established continental population objectives for several shorebird species (Brown et al. 2001). Concurrent with the USSCP, shorebird plans were developed for eleven regions in the U.S. including a North Pacific Shorebird Management Plan that encompasses NPL (Drut and Buchanan 2000). However, the USSCP's population objectives have not been stepped-down to regional plans and nationally derived shorebird populations objectives for NPL are not available.

A suite of priority shorebird species was identified for NPL as an alternative to establishing population abundance objectives. While this approach does not allow shorebird habitat objectives to be quantified using a species-habitat model, it can focus conservation efforts on behalf of regionally important species. Four criteria were used to identify priority shorebird species (defined earlier as species whose biological requirements are emphasized in the NPL plan); 1) a species' relative abundance in NPL: species whose major wintering areas or migration routes fall outside of NPL were not considered as priority species candidates, 2) a species 'continental population trend, and 3) species listed as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service and /or included as a species of high concern on the USSCP's list of High Priority Shorebirds, and 4) the USSCP regional conservation ranking for a species that includes the species' national priority score and an area score that reflects the region's importance to a species' population stability. Twelve priority shorebird species were identified for NPL (Table 12).

Table 12. Priority shorebird species for North Puget Lowlands. Trends in populations are declining (D), Stable (S) or unknown (U). Occurrence (OCC) is defined by species use codes: M = migration, W = wintering, and B = breeding.

	Population[1]		USSCP[2] Priority		
Common Name	**North America**	**Trend**	**National**	**Regional**	**OCC[3]**
Black-Bellied Plover	50,000	D	3	4	**M**,W
Killdeer	1,000,000	D	3	4	**M,W**
Black Oystercatcher	10,000	S	4	4	M,**W,B**
Greater Yellowlegs	100,000	U	3	4	**M**,W
Whimbrel	66,000	S	4	4	**M**,w
Black Turnstone	95,000	U	4	4	M,**W**
Sanderling	300,000	D	4	4	**M,W**
Western Sandpiper	3,500,000	D	3	4	**M**,w
Least Sandpiper	700,000	D	3	3	M,w
Dunlin	550,000	D	3	4	**M,W**
Short-billed Dowitcher	475,000	U	3	4	**M**
Wilson's Snipe	2,000,000	D	3	4	m,**W**,b

[1]Information from Morrison et al. (2006), [2]US Shorebird Conservation Plan
[3]Capitalized, Bold, Italics - species occurs regularly in the region, and management in region is relatively more important than other regions where it occurs; Capitalized - species occurs regularly, and in large enough numbers to warrant management; Lower Case - species occurs rarely to regularly, but not in large enough numbers to warrant management (exclusive of Threatened & Endangered Species).

Waterbirds

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The North American Waterbird Conservation Plan (NAWCP; Kushlan et al. 2002) and the Waterbird Population Estimates 4th Edition (Delany and Scott 2006) contain the most recent continental population estimates and trends for waterbird species regularly occurring in NPL (Table 13). Population estimates and trends are derived from expert opinion and published literature; however, the accuracy and precision of these estimates vary widely because of a notable lack of information for most species. Unfortunately few waterbird counts exist for NPL, making it difficult to estimate what fraction of a species' population occurs in the region.

As an alternative to establishing population objectives, the PCJV chose to first create an "umbrella" framework of waterbird guilds to help guide conservation objectives for this bird group. Waterbirds can be grouped in a variety of ways including, taxonomy, nesting habitat, or foraging habitat. However, classification by foraging habitat is difficult because many species forage near nesting colonies in summer but are broadly dispersed during the non-breeding season when they may use a variety of habitats. As a result, the PCJV grouped common NPL waterbirds according to taxonomic guilds. This approach resulted in a manageable number of guilds for identifying key habitat characteristics and conservation strategies.

Twenty-seven waterbird species that regularly occur in NPL were grouped into one of five taxonomic guilds; 1) loons and grebes, 2) colonial waterbirds, 3) marsh birds, 4) gulls, and 5) alcids. This suite of 27 species was further refined into a list of priority species (Table 14). Three criteria were used to develop this priority list: 1) species identified as being of high or moderate concern in the NAWCP (Kushlan et al. 2002), 2) species listed as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service (2008), and 3) species listed as a Washington State endangered, threatened, or sensitive species or having specific management recommendations for Washington State (Larsen et al. 2004). Finally, the PCJV strove to include at least one or more priority species from each of five taxonomic guilds.

Table 13. North American population estimates and trends for waterbird species that occur in North Puget Lowlands.

Common Name	NA Population[1]	Population Trend[1]
Red-throated Loon	40,000	Declining
Pacific Loon	900,000-1,500,000	Stable
Common Loon	607,000-634,000	Stable/Declining
Horned Grebe	100,000-1,000,000	Unknown
Red-necked Grebe	45,000	Unknown
Pied-billed Grebe	100,000	Stable
Western Grebe	120,000	Declining
Brandt's Cormorant	227,000	Declining
Pelagic Cormorant	103,500	Stable/Declining
Double-crested Cormorant	10,800-21,600	Unknown
Great Blue Heron	Unknown	Stable/Increasing
Great Egret	270,000	Increasing
Virginia Rail	Unknown	Unknown
American Coot	>6,000,000	Stable
Sandhill Crane	515,000-525,000	Stable/Increasing
Bonparte's Gull	255,000-525,000	Stable
Mew Gull	240,000-360,000	Increasing
Ring-billed Gull	2,550,000	Increasing
California Gull	621,000	Stable
Thayer's Gull	<10,000?	Unknown
Glaucous-winged Gull	570,000	Increasing
Heerman's Gull	525,000	Unknown
Caspian Tern	45,000	Increasing
Common Murre	4,250,000	Unknown
Pigeon Guillemot	<69,000	Unknown
Marbled Murrelet	300,000-800,000	Declining
Rhinocerous Auklet	922,000	Stable/Increasing

[1]Information from Delany and Scott (2006) except for Common Murre, Pigeon Guillemot, Marbled Murrelet, and Rhinocerous Auklet. Information for this species was provided by Kushlan et al. (2002).

Table 14. Priority waterbird species in North Puget Lowlands.

Guild / Common Name	Population Trend	NAWCP National Ranking[1]
Loons & Grebes		
Common Loon	Stable/Declining	n/a
Western Grebe	Declining	Moderate Concern
Colonial Waterbirds		
Brandt's Cormorant	Declining	High Concern
Pelagic Cormorant	Stable/Declining	High Concern
Great Blue Heron	Stable/Increasing	Not At Risk
Marsh Birds		
Virginia Rail	Increasing/ Unk	n/a
Sandhill Crane	Stable/Increasing	n/a
Gulls & Terns		
Bonaparte's Gull	Stable	Moderate Concern
Heerman's Gull	Unknown	Moderate Concern
Alcids		
Common Murre	Unknown	Moderate Concern
Pigeon Guillemot	Unknown	Moderate Concern
Marbled Murrelet	Declining	High Concern

[1] See Kushlan et al. (2002) for explanation of species ranking: n/a = species not considered in Version 1 of the NAWCP.

Species Habitat Models and Limiting Factors

Waterfowl

This plan addresses the biological needs of waterfowl during the non-breeding period. Food availability is a key factor limiting waterfowl during migration and winter (Miller 1986, Conroy et al. 1989, Reinecke et al. 1989), and habitat conditions during the non-breeding period may influence reproductive success (Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987, Raveling and Heitmeyer 1989). *The PCJV assumes that food limits waterfowl during the non-breeding period and that providing adequate foraging habitat will ensure that survival outside of the breeding season does inhibit their population growth.*

Joint Ventures have been encouraged to develop biological models that explicitly link bird population objectives to habitat objectives, and to undertake a rigorous analysis of habitat carrying capacity based on these population-habitat models (NAWMP Assessment Steering Committee 2007). The bioenergetics model TRUEMET (CVJV 2006) was used to evaluate current habitat conditions for priority waterfowl species and to inform future habitat objectives. The model provides an estimate of population food energy demand and food energy supplies for specified time periods (Figure 5). Population energy demand is a function of period specific population objectives and the daily energy requirement of individual birds. Population energy supply is a function of the foraging habitats available and the biomass and nutritional quality of foods contained in these habitats. A comparison of energy supply vs. energy needs provides a measure of carrying capacity relative to bird population objectives. Although the model may be useful for assessing current landscape conditions, it can also be used to predict how changes in policy, land use, or habitat programs might impact the birds. Further details on the TRUEMET model are found in Appendix II.

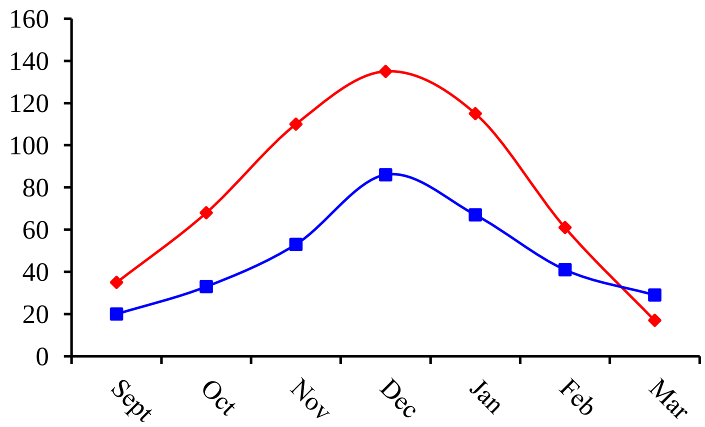

Figure 5. Population food energy demand vs. population food energy supply as estimated by the TRUEMET model in kcal. Food energy supplies are deemed adequate where supply exceeds demand.

Shorebirds

Like waterfowl, this plan largely addresses the needs of shorebirds during the migration and wintering periods. The PCJV assumes that food is a primary need of shorebirds during migration and winter and that providing adequate foraging habitat at appropriate water depths will enhance survival outside of the breeding season.

Bioenergetic models similar to that described for waterfowl in Appendix II have been used by other Joint Ventures to establish habitat objectives for migrating and wintering waterfowl (CVJV 2006, UMRGL JV 2007). However, using a bioenergetic approach in NPL is hampered by several factors including; 1) a lack of shorebird population objectives for NPL, 2) a lack of information on the food items consumed by different shorebird species and the biomass of these food items in important shorebird habitats, and 3) factors that are independent of food density but which affect the quality of shorebird habitat are not well understood (e.g. the relationship between site use and perceived predation risk). As a result, the PCJV used an alternative approach that considered priority shorebird species, the habitats important to these species, and the spatial location of these habitats within the NPL boundary.

Previous work in NPL identified five main types of shorebird habitat used for foraging and roosting; 1) rocky shoreline, 2) estuarine tidal flats, 3) emergent saltmarsh, 4) freshwater wetlands, and 5) agricultural lands (Brennan et al. 1985, Evenson and Buchanan 1997, Slater 2004). All shorebird species that occur in NPL rely on one or more of these habitats, and at least one priority species occurs in each of the five habitat types (Table 15). Earlier work by Evenson and Buchanan (1997) had identified estuarine – freshwater habitat complexes that are especially important to shorebird populations in NPL. This information was combined with the habitat requirements of priority species, as well as with information on the loss of these habitats, to identify spatially explicit conservation actions for shorebirds in NPL.

Waterbirds

Information on the quantity of habitat required by most waterbird species is not well documented. Additionally, habitat needs change throughout the year for species that both breed and overwinter in NPL. Comparatively little NPL-specific information is available for waterbirds and their habitats that would allow inferences to be drawn between the biological or energetic requirements of target waterbird population sizes (not yet estimated) and the amount of habitat needed to meet those requirements.

As with shorebirds, rather than attempting to model species-habitat relationships with inadequate information, the PCJV chose a qualitative approach whereby key habitats are identified for priority waterbird species (Table 16). Ideally, this will allow PCJV partners to evaluate the waterbird benefits that are likely to be provided by a given project. Because many of the NPL's priority waterbird species rely on a mixture of foraging, nesting, and roosting habitats, conservation efforts that enlarge and increase the diversity of existing wetland complexes should be encouraged.

Table 15. Priority shorebird species in North Puget Lowlands and their associated habitats.

Common Name	Habitat Use
Black-Bellied Plover	Coastal and estuarine sand beaches and mud flats; exposed shorelines; wet meadows and farmland
Killdeer	Saltmarsh; exposed shores of ponds, lakes, and rivers; lowland meadows
Black Oystercatcher	Coastal rocky shore
Greater Yellowlegs	Estuarine mud flats; shorelines of shallow ponds, lakes and rivers; flooded fields
Whimbrel	Coastal and estuarine sand beaches and mud flats; salt marsh
Black Turnstone	Coastal rocky shore
Sanderling	Coastal and estuarine sand beaches and mud flats; coastal rocky shore
Western Sandpiper	Coastal and estuarine sand beaches and mud flats; salt marsh; exposed shores of ponds and lakes
Least Sandpiper	Estuarine mud flats; salt marsh; exposed shores of ponds and lakes, freshwater marsh
Dunlin	Coastal and estuarine sand beaches and mud flats; flooded fields
Short-billed Dowitcher	Estuarine mud flats, coastal sand beaches; flooded fields; freshwater marshes
Wilson’s Snipe	Ponds and lakes; freshwater marsh; farmland

Table 16. Priority waterbird species in NPL and their associated habitats

Common Name	Habitat Use
Common Loon	Inland marine waters; also found breeding and wintering on freshwater lakes
Western Grebe	Large numbers winter together on saltwater bays; few in coastal areas during summer
Brandt's Cormorant	Salt or brackish water usually along rocky shorelines or coastal islands
Pelagic Cormorant	Inland marine waters, usually close to shore; breed on small, offshore islands and rocky cliffs with deep water at base
Great Blue Heron	Forage in slow-moving or calm fresh, brackish, or salt water; nesting colonies found in forest, on islands, or near extensive mudflats
Virginia Rail	Found primarily in freshwater marshes and less often in salt/brackish marshes; associated with cattails
Sandhill Crane	Forage in grain fields, pasture, and wet meadows; also found in river valleys during migration
Bonaparte's Gull	Winter in coastal areas, lakes, sewage ponds, estuaries, and open ocean; found during migration in lowland saltwater, sandy-shore, and freshwater habitats
Heerman's Gull	Uses a variety of coastal habitats, including rocky shores, bays, small offshore islands, kelp beds, sandy beaches, and estuaries; not often found at landfills or lakes
Common Murre	Found both in open ocean and in large bays: closer to rocky shorelines during the breeding season, and in deep-water inland marine habitats during the winter
Pigeon Guillemot	Nest along the salt-water coastlines of the NPL in practically every small island or bay; more common and widespread in inland marine habitats in the winter
Marbled Murrelet	Calm, shallow, coastal waters and bays; breed inland, up to 45 miles from shore in mature, wet forest

CONSERVATION DESIGN

The purpose of this section is to establish conservation goals and objectives for NPL. The PCJV's responsibility for wetland dependent birds requires that the goals and objectives of the implementation plan be linked to priority bird needs. However, we broadened the basis for establishing goals and objectives by considering; 1) the historic wetland complex and changes to that complex, and 2) the possible effects of sea level rise (SLR) on coastal wetlands. These additional factors were included because Joint Ventures have assumed much of the responsibility for wetland conservation in the U.S. and they are well positioned to design and deliver habitat programs that address the effects of climate change on wetlands (Figure 6).

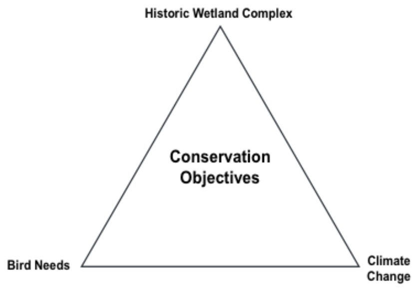

Figure 6. Factors considered when establishing North Puget Lowlands conservation goals and objectives.

The Conservation Design section includes four subsections; 1) Landscape Characterization and Assessment, 2) Evaluation of Existing Bird Habitats, 3) Forecasted Effects of SLR, and 4) Conservation Goals and Objectives. The first section includes a review of NPL's current and historic wetland resources, as well as a review of agricultural habitats important to priority bird species. For waterfowl, the PCJV's evaluation of existing habitats used the bioenergetics model TRUEMET to determine if wetland and agricultural habitats in NPL can meet the food energy needs of target waterfowl populations. For shorebirds and waterbirds the PCJV's evaluation of existing habitats focused on the distribution of birds in NPL, and the loss of habitat types important to these bird groups. Finally, the effects of SLR on tidal and non-tidal habitats were forecasted from now to 2100. Information from these three subsections was then combined to establish goals and objectives for NPL.

Landscape Characterization and Assessment

Wetlands

The PCJV classify wetland habitats in NPL as defined in Cowardin et al. (1979). The U.S. Fish and Wildlife Service adopted this classification system in 1977 for use in the National Wetlands Inventory (NWI), and it is based on a hierarchical structure that includes five major wetland systems and their associated subsystems and classes (Figure 7). More detail on the Cowardin system, as well as historical changes to NPL's wetland complex, can be found in Appendix I.

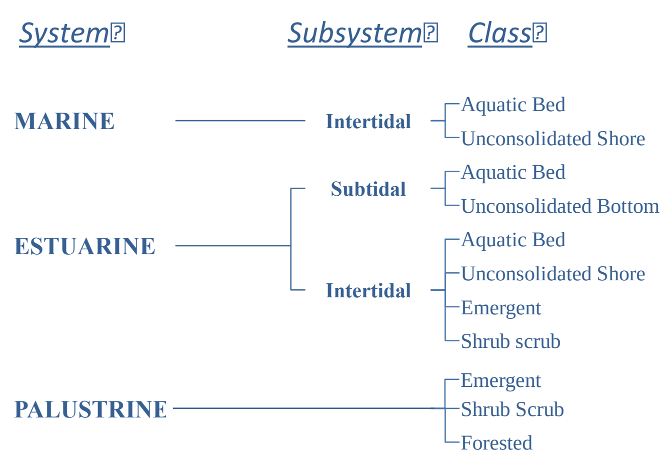

Figure 7. Wetland systems, subsystems, and classes included in the North Puget Lowlands plan. Wetland classification based on the on the Cowardin et al. (1979) system for classifying wetlands and deepwater habitats.

Marine

Marine intertidal and/or estuarine aquatic bed

Marine intertidal and/or estuarine intertidal unconsolidated shore habitat

Habitats that are important to priority bird species occur along a gradient of increasing elevation and decreasing salinity, with marine habitats occurring at the lowest elevations and having salinities greater than 30 parts per thousand. Important marine habitats in NPL include intertidal aquatic bed habitats that support vegetation at or near the surface, and intertidal unconsolidated shore habitats that lack vegetation and where the substrate is usually sand. There are no estimates of the loss of marine habitats in NPL. Aquatic bed habitats now total about 4800 acres, while unconsolidated shore habitats total about 3100 acres (Table 17).

Estuarine

Estuarine intertidal emergent wetland (salt and brackish marshes)

Estuarine intertidal scrub shrub

Estuarine habitats occur adjacent to marine environments and extend landward to where salinity is less than 0.5 parts per thousand. There are nearly 90,000 acres of estuarine habitat in NPL (Table 17). Most acres are classified as aquatic bed or unconsolidated shore / bottom habitats, with no estimates of historic loss. Estuarine emergent wetlands (salt and brackish marshes) are regularly inundated by tides and are dominated by herbaceous perennial plant species. Estuarine intertidal scrub shrub wetlands lie inland of salt and brackish marshes and are characterized by woody vegetation less than 6 m tall. Estuarine emergent wetlands have declined by over 60% since settlement, while estuarine scrub-shrub habitats have virtually disappeared from NPL with a 98% loss rate (Table 17).

Palustrine

Palustrine emergent wetland (freshwater marsh)

Palustrine scrub-shrub wetland

Palustrine forested wetland

Most “freshwater” wetlands included in the PCJV plan fall within the palustrine classification and many palustrine habitats in NPL occur in the floodplains of major river valleys. Three palustrine wetland classes occur in NPL; palustrine emergent, palustrine scrub-shrub, and palustrine forested. Although there are no estimates of palustrine emergent wetland loss, palustrine scrub shrub and palustrine forested wetlands have both declined by over 90% (Table 17)

Lacustrine

The lacustrine system includes wetlands greater than 2 m deep at low water and greater than 8 ha (20 acres) and is divided into limnetic and littoral subsystems. Only wetlands in the littoral subsystem are included in the plan because limnetic habitats are usually too deep to be of value to wetland dependent birds. Although the limnetic subsystem contains six classes only the aquatic bed class is included here. The NWI estimates that there 1,110 acres of lacustrine aquatic bed wetlands in NPL (Table 17). Pre-settlement estimates of lacustrine aquatic bed habitats are lacking, but their greater water depth may have made them more difficult to drain than other wetland types.

Wetland Loss since the 1970's

The NAWMP established waterfowl population objectives based on breeding duck numbers from 1970-1979. Waterfowl populations in the 1970's met the demands of both consumptive and non-consumptive users and habitat conditions during that decade are associated with desired duck numbers. Changes in habitat conditions since the 1970's are of interest to waterfowl managers because they help inform the kind of conservation programs needed to return duck populations to 1970's levels.

Although no analysis of wetland changes since the 1970's has been done for NPL, it is known that the overwhelming loss of many tidal and non-tidal habitats occurred several decades prior to that time. Diking in the Skagit-Samish and Stillaguamish river deltas occurred early; by 1915 few estuarine intertidal emergent or estuarine intertidal scrub shrub wetlands remained and nearly all the freshwater wetlands in these river deltas had been ditched or drained and were no longer shown on topographic maps (Collins 2000).

Diking and draining of estuarine and freshwater wetlands along the Snohomish River occurred later, but was just as complete. Although large areas of freshwater wetlands still remained around 1900, these habitats were largely converted to agriculture by 1950 (Collins 2000). Estimates of wetland loss for the Skagit-Samish, Stillaguamish, and Snohomish River deltas are thought to be representative of the whole NPL, with most loss occurring in the estuarine, palustrine, and lacustrine systems well before the 1970's. Information on the loss of marine habitats and some estuarine habitats is not as complete, but passage of the Coastal Zone Management Act in 1972 likely strengthened the protection of these marine and estuarine habitats.

While most habitat loss occurred prior to the 1970's, further losses may have occurred since then. Without a formal analysis of landscape change since the 1970's it's difficult to know if the capacity of NPL to support wetland dependent birds has diminished over the past 30 years. Areas like the Canadian prairies also suffered their greatest habitat loss prior to the 1970's. However, habitat loss continues in the Canadian prairies and the region can no longer support waterfowl numbers of the 1970's (NAWMP Assessment Steering Committee 2007).

Table 17. Current and historic estimates of wetlands and deepwater habitats in North Puget Lowlands.

Wetland Class	Current Area	Historical Area	Loss (%)
Marine Intertidal			
Aquatic Bed	4,800	-	-
Unconsolidated Shore	3,100	-	-
Estuarine Subtidal			
Aquatic Bed	200	-	-
Unconsolidated Bottom	24,100	-	-
Estuarine Intertidal			
Aquatic Bed	39,100	-	-
Unconsolidated Shore	14,200	-	-
Emergent	9,700	26,300	63
Scrub-Shrub	300	12,500	98
Palustrine			
Scrub-Shrub	2,700	34,300	92
Forested	2	9,800	≥99
Emergent	1,500	-	-
Lacustrine			
Aquatic Bed	1,100	-	-

Agriculture

Farmland plays an important role in meeting the food energy needs of NPL waterfowl and shorebirds (Lovvorn and Baldwin 1996), and maintaining bird populations at desired levels may partly depend on how agricultural environments evolve to the benefit or detriment of waterfowl and shorebirds. This section describes the agricultural landscape of NPL, including past changes and forecasted trends.

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The amount of land in farms has been estimated at five year intervals for NPL counties since1982. Between 1982 and 1997 total farmland declined from 370,740 acres to 290,470 acres or 22%. This loss rate was among the highest in the U.S., and surpassed loss rates for the Central Valley of California where waterfowl and shorebirds are also heavily dependent on agriculture. Farmland loss was highest in Snohomish County where 35% of all agricultural land was converted to other uses during this fifteen year period --- and where nearly 50% of the mid-winter dabbling duck population occurs in NPL (Table 5).

Between 1997 and 2007, farmland in NPL increased from an estimated 290,470 acres to an estimated 327,133 acres. However, Census of Agricultural data collected after 1997 are not comparable to data from prior years. After 1997, data was adjusted to account for farms missed or misclassified during the census causing an *apparent* increase in farmland that is likely due to changes in how the census is conducted (McMoran 2007). Census data after 1997 can be compared because agricultural statistics were gathered using the same methods. Between 2002 and 2007, NPL farmland declined a further 10%. Thus, data that is evaluated over periods of similar census methods (i.e. 1982-1997 and 2002 to 2007) suggests a steady decline in NPL farmland over the past twenty five years.

The causes of farmland loss in NPL are largely related to declines in profitability that results from increasing production costs, including regulatory costs, and stagnant or declining market prices. These problems are compounded by the increasing value of agricultural land for residential home sites, which can result in higher property taxes and major cost increases to farmers that remain in business in developing areas. High land prices also prevent farmers from expanding their farms, and are often crucial in farmers and their heirs deciding to sell farms to land developers and leave the industry. As a result of urban development, the Puget Sound region is considered the 5th most threatened agricultural area in the country. The loss of farmland also jeopardizes the minimum acre base needed to support food processors and other farm service businesses. Loss of local processors increases transportation and processing costs, accelerating the decline of agriculture land on the urban fringe (Canty and Wiley 2004).

In addition to total changes in farmland, changes in crop types important to waterfowl were also examined, including corn, potatoes, barley, oats, and winter cover crops that are planted in fall to improve soil characteristics. Corn has been an important crop in NPL for decades, although all corn is grown as silage. This results in less waste grain than conventionally harvested fields, though waterfowl in NPL do forage in silage fields (Baldassare and Bolen 1984, Garret pers. comm.). Between 1974 and 2007, silage corn increased from 15,000 to 27,400 acres (NASS 2013; Figure 8). Almost all of this production occurs in Skagit, Snohomish, and Whatcom counties (Table 18).

Table 18. Agricultural crops (acres) important to waterfowl in North Puget Lowland counties.

County	Corn Silage	Potatoes	Barley	Cover Crops
Skagit	5,900	9,500	700	15,000
Snohomish	4,900	0	0	2,000
Whatcom	16,600	2,000	0	10,000
Island	0	0	0	0
San Juan	0	0	0	0
Total	27,400	11,500	700	27,000

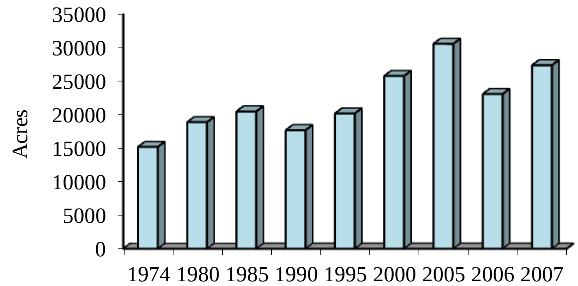

Figure 8. Acres of corn silage grown in North Puget Lowlands between 1974-2007.

Research in the nearby Fraser River Delta indicates that waste potatoes are an important food source for migrating and wintering waterfowl (Dan Buffet pers. comm.). Between 1970 and 2007 potato production increased from 3400 to 11,500 acres (NASS 2013; Figure 9), mostly in Skagit County (Table 18).

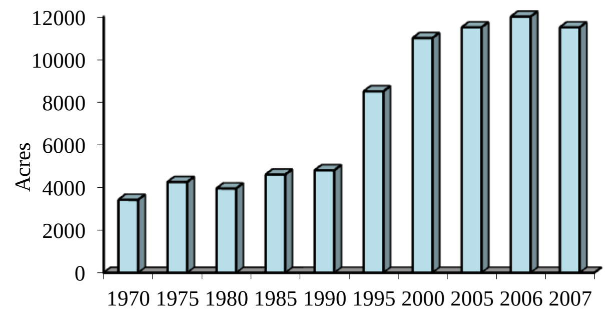

Figure 9. Acres of potatoes grown in North Puget Lowlands between 1970-2007.

Barley is also widely recognized as a preferred waterfowl food in NPL and barley production increased from the early 1970's through the early 1980's when it began to decline (Figure 10).

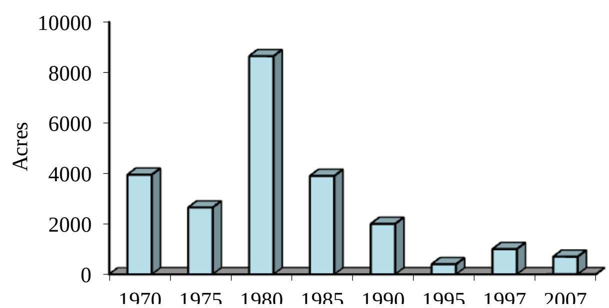

Figure 10. Acres of barley grown in North Puget Lowland between 1970-2007.

Today, less than 1000 acres are planted in NPL (NASS 2013). Oat production has undergone a similar decline, reaching a peak of 10,000 acres in 1978 before declining to under 2000 acres by the early 1990's (Figure 11). Today, no oat production is reported for any NPL county (NASS 2013; Table 18).

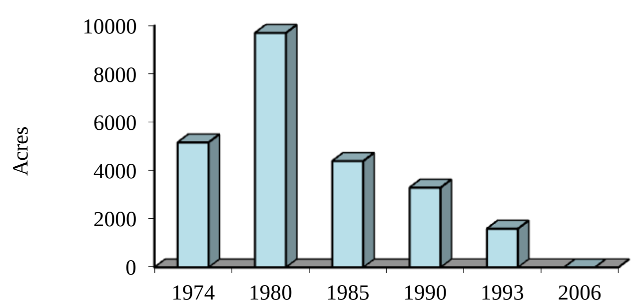

Figure 11. Acres of oats grown in North Puget Lowlands between 1974-2006.

The practice of planting fall cover crops or "green manure" has become widespread in NPL. Cover crops include winter wheat, rye grass, or oats that are seeded in fall and plowed under in spring prior to planting commercial crops, although some (e.g. winter wheat) are harvested. Farmers in NPL began planting cover crops in the mid-1980's after research showed that cover crops improved nutrient retention and reduced soil erosion. Today, an estimated 27,000 acres of farmland is seeded to cover crops in fall (Table 18).

Evaluation of Existing Bird Habitat

Waterfowl Carrying Capacity Analysis

The fundamental need of waterfowl during migration and winter is food. By providing adequate foraging habitat, the PCJV can help ensure that waterfowl populations are not limited by low survival outside of the breeding season and that birds arrive on the breeding grounds in good condition. The PCJV used the bioenergetics model TRUEMET (CVJV 2006) to determine if foraging habitats in NPL can meet the food energy needs of priority waterfowl species. Details on the TRUEMET model, as well as a full description of model inputs and results are presented in Appendix II. A general overview of the carrying capacity results for priority species is presented below.

Brant

Pacific brant rely almost exclusively on eelgrass to meet their food energy needs. The capacity of native eelgrass in NPL to support brant at population objective levels from November through May was modeled by assuming that 100% of eelgrass leaf biomass is available to brant. The results of this carrying capacity analysis suggest that the food energy supplied by eelgrass in NPL is well above brant population energy needs in all time periods (Figure 12).

Brant prefer the inner leaves of eelgrass and avoid older leaves that are often thickly covered by epiphytes (J. Black pers. Comm.), so the assumption that all leaf biomass is available for consumption is undoubtedly false. In addition, wigeon consume some eelgrass and further reduce the amount of food available to brant. To account for wigeon consumption and the fact that brant avoid older leaves, TRUEMET was used to estimate the percent of total leaf biomass needed to meet brant needs. Results indicate that brant populations in NPL only require about 33% of eelgrass leaf biomass to meet their food energy requirements, and the Joint Venture assumes that eelgrass is probably sufficient to support brant at population objective levels.

Dabbling Ducks

Mallards, pintails, and wigeon make up over 90% of all dabbling ducks in NPL. While each of the species consumes agricultural foods, there are differences in the types of crops used. Mallards and pintails forage in harvested potato fields, harvested silage fields, and fields of standing barley and corn that are intentionally grown for waterfowl. The latter includes both public and private lands managed for waterfowl hunting. In contrast, most wigeon forage on agricultural lands that are planted to fall cover crops like winter wheat or rye grass and which provides an abundance of green forage.

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Although mallards and pintails meet some of their food energy requirements from intertidal and freshwater habitats, most of their food is likely acquired from agricultural lands (see Appendix II: carrying capacity of intertidal and freshwater habitats for mallards and pintails). As a result, the Joint Venture evaluated the capacity of agricultural lands to meet the food energy needs of mallards and pintails from fall through spring. The results from TRUEMET indicate that agricultural habitats can meet 100% of mallard and pintail food needs from September through April, even if the Joint Venture assumes that these species acquire few of their food resources from intertidal habitats or freshwater wetlands (Figure 13). Mallards and pintails undoubtedly consume some foods in these non-agricultural habitats, and the food surplus suggested by Figure 13 should be considered a minimum. Snow geese and swans are also assumed to forage in these agricultural habitats, and their effects on mallard and pintail food supplies are included in the TRUEMET analysis.

Because of interspecific differences in habitat use, the PCJV conducted a separate capacity analysis for wigeon. It was assumed that wigeon could meet their food energy needs from eelgrass beds prior to October 1. After this date, they were assumed to rely primarily on fall cover crops. The results from TRUEMET indicate that food supplies for wigeon are well above population energy needs in all time periods, mostly due to the fact that over 27,000 acres of fall cover crops are now planted in NPL (Figure 14). Snow geese and swans are also assumed to forage on cover crops and their effects on wigeon food supplies are included in the TRUEMET analysis.

Wrangel Island Snow Geese

Wrangel Island snow geese are assumed to forage in harvested potato fields, harvested silage fields, fields of standing barley and corn that are intentionally grown for waterfowl in NPL, and in fall cover crops. Results from TRUEMET indicate that these food sources can meet 100% of snow goose energy needs from September through April with a large food surplus remaining (Figure 15). Most of this food surplus is attributed to the abundance of fall cover crops.

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Swans

Trumpeter and Tundra swans are assumed to forage in harvested potato fields, harvested silage fields, fields of standing barley and corn that are intentionally grown for waterfowl in NPL, and in fall cover crops. Results from TRUEMET indicate that these food sources can meet 100% of swan energy needs from September through April with a large food surplus remaining (Figure 16). Most of this food surplus is attributed to the abundance of fall cover crops.

Diving Ducks and Sea Ducks

Carrying capacity analyses were not possible for diving ducks or sea ducks. This was mostly due to the fact that the PCJV lacked data on the food supplies available to diving ducks and sea ducks in intertidal and marine habitats used by these birds. Future research in NPL should address these information shortfalls.

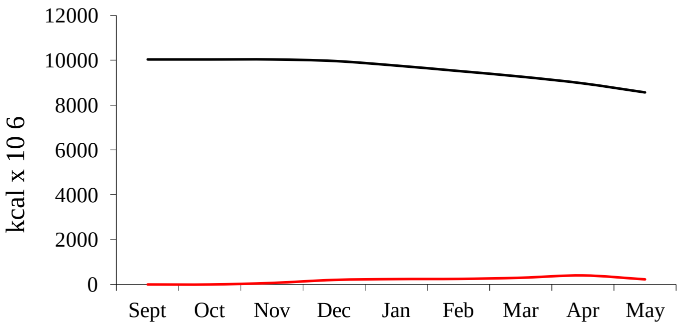

Figure 12. Brant food energy supply (black) vs. population energy demand (red).

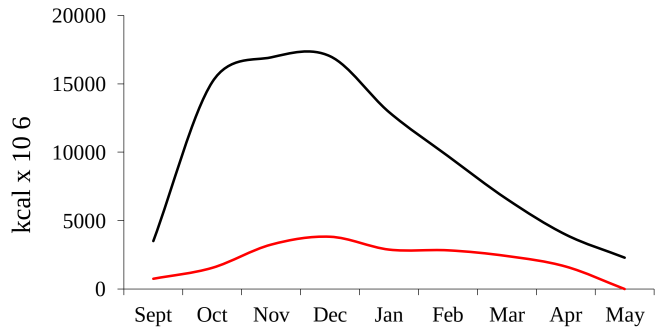

Figure 13. Mallard and pintail food energy supply (black) vs. population energy demand (red).

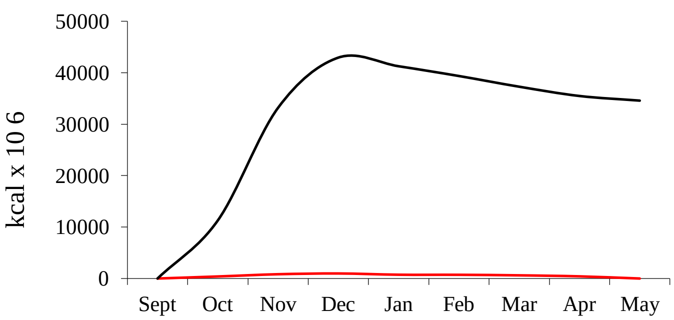

Figure 14. Wigeon food energy supply (black) vs. population energy demand (red).

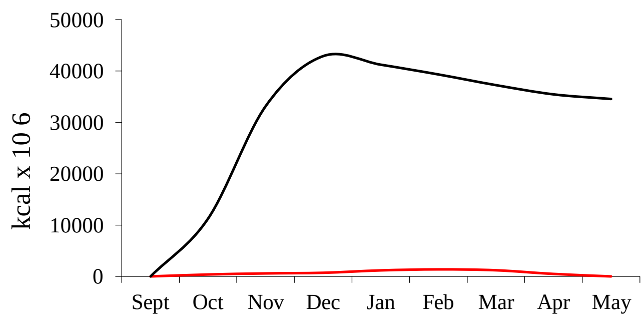

Figure 15. Snow geese food energy supply (black) vs. population energy demand (red).

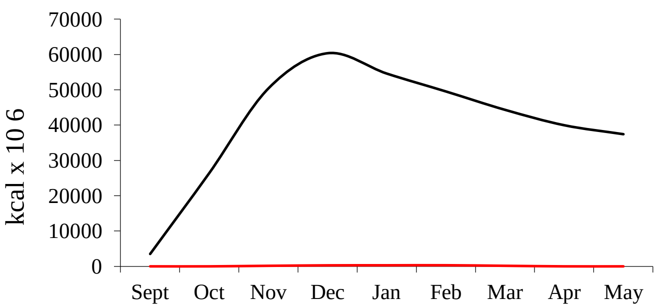

Figure 16. Swan food energy supply (black) vs. population energy demand (red).

Habitat Use and Distribution of Shorebirds

Priority shorebird species in NPL rely on one or more of the following habitat types; 1) rocky shoreline, 2) estuarine tidal flats, 3) emergent saltmarsh, 4) freshwater wetlands, and 5) agricultural lands (Table 15). Estuarine tidal flats, emergent saltmarsh, and freshwater wetlands correspond to Cowardin et al. (1979) wetland classes that are important in NPL, and for which we have information on current and historic abundance. For example, "emergent saltmarsh" corresponds to the wetland class "estuarine intertidal emergent", while "freshwater" wetlands correspond to several palustrine wetland classes listed in Table 17. Many of the wetland types important to shorebirds have undergone dramatic declines. Saltmarsh has declined 63% since Euro-American settlement, while many classes of freshwater have declined by more than 90% (Table 17).

Evenson and Buchanan (1997) identified a number of sites used by shorebirds in the NPL during aerial and ground counts of 66 Puget Sound sites over seven non-breeding seasons (Table 19). These sites varied from large river estuaries that provided a diversity of tidal habitats, to rocky shoreline subject to higher wave action. Four large estuaries had counts of > 20,000 shorebirds each year: Samish Bay, Padilla Bay, Skagit Bay, and Port Susan Bay (Figure17). All four sites qualify for Western Hemisphere Shorebird Reserve Network (WHSRN) "regional importance" status, and together host between 50% and 90% of the wintering shorebird population found in the Greater Puget Sound area (Evenson and Buchanan 1997).

Table 19. Peak counts of shorebirds at sites in North Puget Lowlands between 1990 and 1996. Data from Evenson and Buchanan 1997.

	Peak Seasonal Counts 1990-1996		
Site	**Winter**	**Spring**	**Fall**
Drayton Harbor	6,911	8,827	6,646
Birch Bay	3,000	n/a	2,253
Lummi Bay	5,126	3,028	n/a
Bellingham Bay	3,117	1,933	n/a
Samish Bay	14,000	27,527	2,665
Padilla Bay	11,572	30,944	2,072
Skagit Bay	29,606	21,215	12,413
Port Susan Bay	31,050	50,103	50,008
Snohomish River Delta	3,507	4,520	1,613
Chuckanut Bay	n/a	4,663	n/a
Fidalgo Bay	3,658	4,027	n/a

n/a: not available

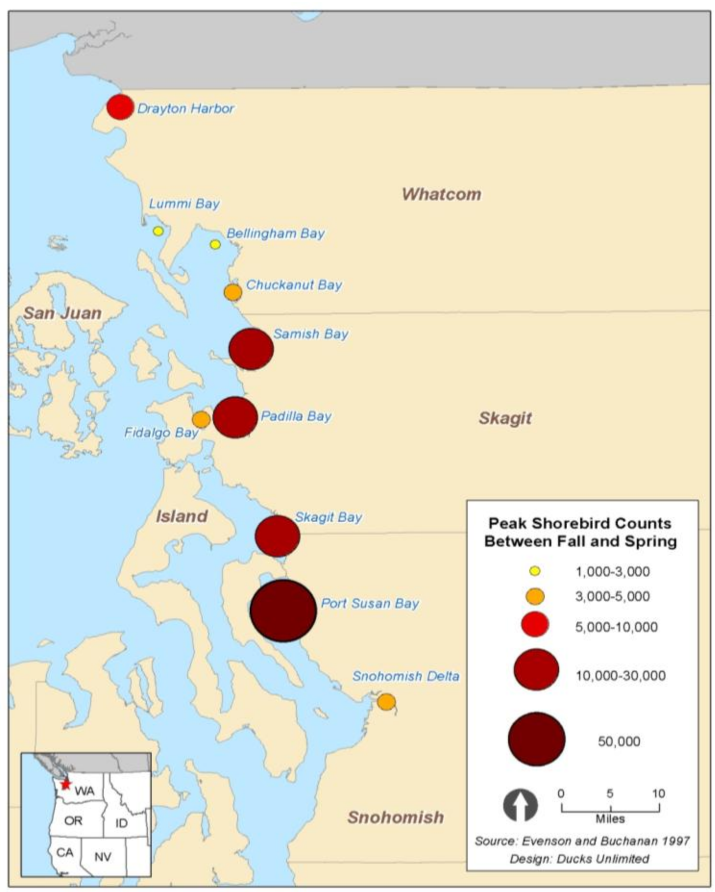

Figure 17. Peak shorebird counts in North Puget Lowlands estuaries.

Habitat Use and Distribution of Waterbirds

Priority waterbird species in NPL occupy a continuum of habitats from open ocean to inland freshwater wetlands, to terrestrial habitats that support nesting colonies of breeding birds (Table 16). The Washington Department of Fish and Wildlife's Puget Sound Ambient Monitoring Program (PSAMP) has conducted aerial surveys of selected waterbird species since 1992, and has collected this data in a Marine Bird Density Atlas. The Atlas provides information on the density of waterbird species throughout Puget Sound (Figure 18). Maps for priority waterbird species that are included in the Marine Bird Density Atlas are found in Appendix III. These maps, in conjunction with the habitat needs of priority species (Table 16), can be used to focus conservation efforts on behalf of waterbirds.

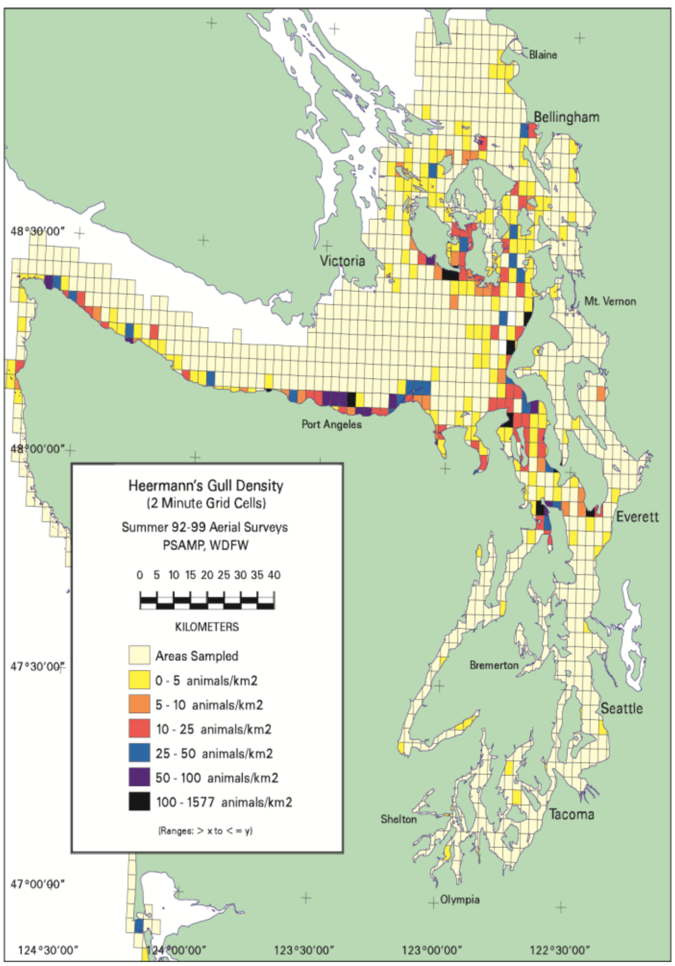

Figure 18. Marine Bird Density Atlas results for Heerman's Gull, a priority waterbird species in North Puget Lowlands.

Sea Level Rise (SLR)

There is overwhelming evidence that human activities, in particular the burning of fossil fuels, have resulted in excessive amounts of CO_2 and other greenhouse gases in our atmosphere. As a result, the earth's average surface temperature is increasing and IPCC projections suggest that surface temperatures will continue rise by another 1.1-6.4 degrees Celsius before the turn of the century. One consequence of global warming is a rise in sea levels that results from thermal expansion of the oceans and rapidly melting glaciers and polar ice sheets.

Although some wetland classes in NPL have declined by more than ninety percent (Table 17), efforts to protect and restore wetlands have slowed this decline. Unfortunately, SLR may reverse this progress and result in further loss of coastal habitats. The National Wildlife Federation (NWF) examined the possible effects of SLR on coastal habitats in the Pacific Northwest, including those in NPL, using the Sea Level Affecting Marshes Model or SLAMM (Glick et al. 2007). The NWF report examined the effects of SLR in terms of coastal habitat loss and the inundation of freshwater ecosystems with saltwater. The PCJV used the results of this report to better understand how climate change is likely to impact tidal and freshwater habitats, and to develop adaptation strategies that address these changes.

Forecasted Changes in Tidal and Freshwater Habitats

Sea level has risen in the geologic past. Although coastal wetlands were "drowned" during these earlier periods of SLR, new bands of coastal wetlands formed inland of these old estuaries as wetlands migrated upslope. In general, these were self mitigating systems that allowed coastal wetlands to persist despite changing sea levels. However, much of the Pacific coast has been modified by levees, seawalls, and other armoring that now prevents the upslope migration of coastal wetlands (Glick et al. 2007). Coastal habitats that lie seaward of these barriers may be converted to open water because of rising seas, while inland habitats may undergo changes in vegetation types due to saltwater intrusion.

The NWF report predicts changes from SLR for multiple habitat types and multiple SLR scenarios ranging from 0.39 m to 1.5 m between now and 2100. Many of the habitat types included in the NWF report correspond directly to major Cowardin et al. (1979) wetland classes found in NPL. Eleven Cowardin wetland classes occur in NPL (Figure 7), of which eight are included in the NWF report. To evaluate the impacts of sea level rise, NPL's 11 wetland classes were combined into five "nearshore zones" arranged along a gradient of increasing elevation and decreasing salinity (Table 20). More details on how the PCJV used the NWF report to evaluate the effects of SLR on NPL habitats can be found in Appendix IV. The results presented here are for a SLR scenario of 0.69 m between now and 2100, although results for all scenarios between 0.39 m and 1.5 m are included in Appendix IV.

The five nearshore zones varied widely in terms of the forecasted effects of SLR (Table 21). Low tidal habitats are predicted to decline by nearly 30% by 2100. Most of this decline occurs between 2025 and 2050, with a modest increase in low tidal habitats between 2050 and 2100. In contrast, the amount of saltmarsh is expected to experience little change over the next ninety years. Saltmarsh, or estuarine intertidal emergent wetlands, have declined by over 60% since Euro-American settlement (Table 17). Interestingly, the transitional nearshore zone is expected to increase by over 200%. This nearshore zone includes the "estuarine intertidal scrub-shrub wetland class", a habitat that has declined by over 90% (Table 17). Conversely, wetland classes in the freshwater tidal and freshwater nearshore zones are predicted to decline 64% and 13% respectively (Table 21).

Table 20. Grouping of wetland classes in North Puget Lowlands into five "nearshore" zones used to evaluate the possible effects of sea level rise.

Nearshore Zone	Habitat Types	Corresponding Cowardin Classification[a]
Low Tidal	Ocean Beach	Marine intertidal unconsolidated shore
	Estuarine Beach	Estuarine intertidal unconsolidated shore (mud)
	Tidal Flat	Estuarine intertidal unconsolidated shore (sand)
Saltmarsh	Saltmarsh	Estuarine intertidal emergent
Transitional	Transitional Marsh	Estuarine intertidal scrub-shrub
	Brackish	Estuarine intertidal emergent
Freshwater Tidal	Tidal Fresh Marsh	Palustrine emergent (Tidal modifier)
	Tidal Swamp	Palustrine forested (Tidal modifier)
	Tidal Swamp	Palustrine scrub-shrub (Tidal modifier)
Freshwater Non-Tidal	Inland Fresh Marsh	Palustrine emergent
	Inland Fresh Marsh	Lacustrine Aquatic Bed
	Swamp	Palustrine forested
	Swamp	Palustrine scrub-shrub

[a] Cowardin classes that correspond to a Habitat Type in the NWF report and which occur in North Puget Lowlands.

Table 21. Changes in the number of acres of wetland habitat types in nearshore zones between now and 2100 that result from a sea-level rise of 0.69 m and removal of all dikes.

Nearshore Zone	Current Conditions	0.69 m Sea Level Rise	0.69 m SLR & Dike Removal
Low Tidal	12,659	9,224	19,620
Saltmarsh	5,701	5,836	36,391
Transitional	640	2,133	9,752
Freshwater Tidal	1,630	588	463
Freshwater	21,495	18,607	15,123

Forecasted Changes in Tidal and Freshwater Habitats with Dike Removal

Large areas of NPL are protected by dikes both for urban development and agricultural purposes. These dikes can severely impact the ability of coastal wetlands to migrate upslope as happened during earlier periods of SLR. Dikes were "theoretically" removed in SLAMM for the NWF report, and coastal habitats were allowed to migrate upslope under various SLR scenarios. The PCJV examined changes in each of the five nearshore zones when dikes were removed and sea level increased 0.69 m by 2100.

Removing dikes in SLAMM clearly demonstrated the ability of coastal habitats to migrate upslope in response to SLR (Table 21). Habitat gains in nearshore zones ranged from a 55% increase in low tidal habitats, to a 1400% increase in transitional wetlands (this last increase partly due to the low acreage of existing transitional habitats). In contrast, wetland habitats in the freshwater – tidal and freshwater nearshore zones declined, presumably as a result of saltwater intrusion. These results suggest that allowing coastal wetlands to migrate inland in a carefully planned way may offer a practical solution to SLR. However, providing nature a future right-of-way along our coasts will require that some of that coast remain free of development.

Conservation Goals and Objectives

The PCJV distinguishes between goals and objectives in the NPL plan, although these terms are often used in an interchangeable manner. For the purposes of this plan, goals are considered to be conceptual statements that guide the establishment of quantifiable conservation objectives (Tear et al. 2005). Conservation goals and objectives were established only after considering; 1) habitat needs of priority bird species and the extent to which the NPL landscape currently meets those needs, 2) changes to the historic wetland complex since Euro-American settlement, and 3) possible effects of climate change, in particular SLR (Figure 6).

Three conservation goals were established for NPL; 1) preservation of agricultural landscapes, 2) a wetland complex that reflects the historical abundance of important wetland classes, and 3) increased resiliency of NPL coastal habitats to sea level rise. The PCJV's goal to help preserve agricultural landscapes is directly related to the food resources that agricultural habitats provide for priority bird species. In fact, carrying capacity analyses strongly suggest that many of these priority species could not be maintained at population objective levels in the absence of agriculture. However, farmland preservation is also important for preserving future conservation opportunities, including wetland restoration and adaptation to SLR. The goal of restoring "historical balance" to the region's wetland complex reflects the virtual extinction of wetland classes that were once abundant in NPL, and which likely provided important ecological functions. Finally, increasing the resiliency of coastal habitats to SLR recognizes that climate change may severely impact wetlands along much of the Pacific Coast, including NPL.

Preservation of Agricultural Landscapes

Carrying capacity analyses done by the PCJV demonstrated the importance of agricultural habitats to priority waterfowl species in NPL. The TRUEMET model can also be used to estimate the minimum amount of agricultural habitat needed by priority species; for instance, how many acres of fall cover crops are needed by Wrangle Island snow geese? While they help inform bird needs, these estimates were not generated since farmland protection efforts that are narrowly focused on waterfowl needs are unlikely to succeed. Instead, the JV advocates large scale efforts to protect farmland across the entire NPL. While cropping patterns and agricultural practices may change over time, the PCJV believes that a functioning agricultural landscape will continue to provide significant bird benefits despite these changes. The Puget

Sound region is the fifth most threatened agricultural area in the U.S. due to urban development, and this continuing loss of farmland jeopardizes the minimum acre base needed to support food producers and other farm service business, as well as the sophisticated crop rotation patterns typical of NPL farming. Piecemeal efforts to protect agricultural habitats for birds may ultimately be undermined by the larger issue of farmland loss.

In lieu of establishing quantified farmland protection objectives on behalf of priority bird species, the PCJV established the following objectives:

- Inform policy makers and resource managers about the role of agriculture in meeting migratory bird needs in NPL.
- Expand funding for farmland easements programs in NPL. Farmland easements are an excellent tool for permanently protecting farmland because they prevent future development of the property, but allow landowners to farm indefinitely. In turn, landowners receive a cash settlement for the sale of their development rights. Informing policy makers and resource managers about the importance of agriculture to bird populations in NPL may help increase funding for farmland easement programs.

Restoring the Historic Wetland Landscape

Wetland loss in NPL far exceeds the national average (usually assumed to be about 50%), and some wetland classes have virtually disappeared from the landscape (Table 19). The NPL wetland complex has not only suffered a high rate of wetland loss, but some wetland classes are now severely underrepresented relative to historic conditions. Restoration objectives were established for wetland classes for which current and pre-settlement estimates were available, and which are known to have been important in the historic wetland complex. Restoration objectives were calculated based on the amount of restoration needed to return these wetland classes to 25% and 50% of historic levels (Table 22).

Table 22. Wetland restoration objectives (acres) for North Puget Lowlands

	Area (acres)		Restoration	
Wetland Class	Current	Historical	25%	50%
Estuarine Intertidal Emergent	9,700	26,300	Achieved	3,500
Estuarine Intertidal Scrub-Shrub	300	12,500	2,800	6,000
Palustrine Scrub-Shrub	2,700	34,300	5,900	14,500
Palustrine Forested	2	9,800	2,500	4,900

The wetland restoration objectives listed in Table 22 are for the entire NPL. However these restoration objectives should be distributed in a way that reflects the historic distribution and loss of wetlands in NPL, and which maximizes the benefits for priority bird species. Fortunately, the reconstruction of NPL's historic wetland complex also provided information on how pre-settlement wetlands were distributed among NPL's five-county area (Collins and Sheikh 2005). The PCJV used this information to partition NPL wetland objectives among counties (Table 23).

Table 23. North Puget Lowlands wetland restoration objectives (acres) by county.

	County					
Wetland Class	Snohomish	Skagit	Whatcom	Island	San Juan	Total
Estuarine Intertidal Emergent	1,225	1,785	280	175	35	3,500
Estuarine Intertidal Scrub-Shrub	2,100	3,060	480	300	60	6,000
Palustrine Scrub-Shrub	5,075	7,395	1,160	725	145	14,500
Palustrine Forested	1,715	2,500	390	245	50	4,900

Not surprisingly, wetland restoration objectives are highest for Snohomish and Skagit counties. Together, these two counties contained most of the wetland habitat found in NPL prior to Euro-American settlement. Population objectives for both dabbling ducks and diving ducks are also highest for these two counties (Tables 5 & 6), so restoration objectives that are based on the historic distribution of wetlands seems appropriate for these two bird groups. Wetland restoration objectives weighted by county are also consistent with the distribution of shorebirds in NPL. Shorebird counts are highest for key estuaries in Snohomish and Skagit counties, while Whatcom County also supports significant numbers of shorebirds (Figure 18).

Wetland restoration objectives that are based on the pre-settlement wetland complex may partially offset information gaps for key bird species, if we assume that these species partially evolved in response to historic habitat conditions.

Wetland Protection

Protection of existing wetlands using fee title purchases or conservation easements has been a focus of the PCJV since its inception, and most of the Joint Venture's accomplishments have been categorized as "protection." Protection is now viewed by many as the most effective use of conservation resources, primarily because restoration is often expensive. Failing to protect existing habitats will inevitably increase future restoration costs. It is difficult to establish a numeric wetland protection objective as there are no good estimates of the amount of unprotected habitat in NPL. The PCJV assumes that all unprotected wetlands are candidates for protection given how few historic wetlands remain; essentially a wetland protection objective of 100%.

Increasing the Resiliency of NPL Coastal Habitats to Sea Level Rise

Allowing coastal wetlands to migrate inland in a carefully planned way may be the only practical solution to SLR. However, providing nature with a future right-of-way requires that we maintain parts of the coast free from development. Although some of the NPL shorefront has been developed, most of it remains in agricultural production. Farmland easements are a commonly used tool to preserve agricultural lands, especially where development pressure is intense. Government or non-government organizations can purchase the development rights from a landowner, but the landowner maintains ownership of the land and is allowed to farm in perpetuity. Such easements can help maintain the agricultural landscape, while also providing a substantial one-time payment to landowners.

Keeping shorefront farms and forests free of development is particularly important because these properties are the best candidates for mitigating the effects of SLR. Allowing coastal wetlands to migrate upslope onto these lands can offset the loss of coastal habitats elsewhere. Farmland easements on shorefront farms and forests would place *no requirements* on landowners to open their land to the sea. Landowners could continue to farm indefinitely, regardless of SLR. However, if SLR predictions prove correct, landowners may face increased dike maintenance costs, saltwater intrusion into soils, and drainage difficulties. At some point, a landowner could place the property on the "conservation buyers market", assuming that the property in no longer of interest to the agricultural market. A conservation buyer would presumably purchase the property and assume the cost of restoration. The PCJV recognizes that securing a farmland easement on shorefront land provides no guarantee that this land will be restored to coastal habitat, even if sea level rises. However, we can be certain that if these shorefront lands are developed the opportunity to restore them will be gone. Keeping these areas free of development, and in farmland, is the first and most important step in providing future generations a reasonable option for addressing sea level rise in NPL.

The PCJV proposes an initial objective of seeking farmland easements on 5,000 acres of shorefront farms in NPL. Although SLAMM is typically used to forecast the effects of SLR, it can also be used to predict the types of coastal wetlands that will develop when tidal action is restored to shorefront lands and some amount of SLR is assumed. The

PCJV's interpretation of the NWF report is that habitats in the low tidal nearshore zone will suffer the greatest loss under most SLR scenarios, and that this loss totals about 3,500 acres (Table 22). Accordingly, easements should be sought on shorefront lands that are most likely to evolve into low tidal habitats if restored.

The PCJV's 5,000 acre easement objective and its focus on low tidal habitats should be considered a first step in increasing the resiliency of coastal habitats to SLR. Trying to forecast the consequences of SLR fifty to ninety years out is inevitably accompanied by a high degree of uncertainty, and future data and better models may generate very different results in terms of the amount and types of wetland classes that will be lost to SLR. The only way to address such uncertainty is to seek easements on as many shorefront properties as possible, which will increase our capacity to address SLR regardless of how it ultimately affects our coastline. Finally, farmland easements on shorefront properties contribute to the PCJV's goal of farmland preservation even if sea level does not rise.

Decision Support Tools

Strategic Habitat Conservation (SHC) emphasizes the questions "How much" and "Where?" While the PCJV's conservation objectives partially address the question of "How Much", they do not address the issue of "Where?" Spatially - explicit decision support tools can help joint venture partners to decide where in a geographic area they should focus their efforts to meet the PCJV's conservation objectives. The PCJV has developed, or is in the process of developing, decision support tools related to the joint venture's wetland restoration and farmland easement objectives.

Farmland Easements for Adapting to Sea Level Rise

The PCJV's sea level rise analysis suggests that low tidal habitats will suffer the greatest loss, and that farmland easements should be sought on shorefront lands in NPL that are most likely to evolve into low tidal habitats when restored. A decision support tool is now being developed that will help identify where easements should be sought to offset forecasted declines in coastal habitat, like that identified for NPL. This tool will rely on SLAMM to predict what kind of coastal habitat type will evolve at a specific site if the dikes protecting this site are set back, and sea level rises by a set height in the model.

The SLAMM used in this decision support tool will be the 6.1 stochastic version. Thus, the PCJV can estimate the probability that a site now protected by dikes will evolve into a specific habitat type (e.g. multiple simulations incorporating measures of variance for important model inputs may suggest that a given parcel of land has a 80% probability of evolving into low tidal habitat at a 0.69 m SLR if dikes protecting the site are set back). In an estuary where low tidal habitat is likely to be lost regardless of the SLR scenario, easements may be sought mostly on lands having a high probability of evolving into this habitat type. Conversely, if projected changes in coastal habitat vary widely depending on the SLR scenario choosing an easement strategy that is more variable and thus robust mat be preferred. Finally, other GIS layers (e.g. parcel boundaries, existing infrastructure etc) that may be important in developing an easement strategy will be included as part of this tool. The PCJV anticipates that this decision support tool will be fully developed by winter 2013, and that it will be applied along the entire length of the WA and OR coasts.

APPENDICES

Appendix I. Historic and Existing Habitats

Wetlands

To describe existing and historic wetland habitats the JV relied on the Cowardin et al. (1979) system for classifying wetlands and deepwater habitats. The U.S. Fish and Wildlife Service adopted this classification system in 1977 for use in the National Wetlands Inventory (NWI) and it is based on a hierarchical structure that includes five major wetland systems and their associated subsystems and classes (Figure 7). These categories are useful for evaluating landscape conditions relative to bird population goals and for describing changes in the overall wetland environment including possible effects of sea level rise. An inventory of existing wetlands in NPL was obtained from the NWI with most wetlands identified to the "class" level, which describes the general appearance of the habitat in terms of either the dominant form of vegetation (e.g. trees vs. herbaceous plants) or the composition of the substrate (e.g. cobble – gravel vs. organic matter). Attributes that distinguish wetlands at the class level are the same regardless of the system or subsystem in which they occur. For example, "aquatic bed" class wetlands are defined as wetlands that are dominated by plants growing on or below the water surface regardless of the system or subsystem in which they occur. However, plant species found in marine aquatic bed habitats will obviously differ from species found in palustrine aquatic bed wetlands.

Marine

Habitats that are important to priority bird species occur along a gradient of increasing elevation and decreasing salinity, with marine systems occur at the lowest elevation where they are exposed to the waves and currents of the open ocean. Marine habitats extend from the outer edge of the continental shelf to the seaward limit of the estuarine system, with salinities exceeding 30 parts per thousand and with little or no dilution except at the mouths of estuaries. Marine systems are further divided into two subsystems; 1) subtidal, where substrates are continuously submerged, and 2) intertidal, where the substrate is exposed and flooded by tides. The NPL focus area lacks marine subtidal habitats that are important to waterfowl, but two intertidal classes are included in the plan; 1) aquatic bed, which support vegetation at or below the surface, and 2) unconsolidated shore, which includes all habitats having unconsolidated substrates with less than 75% cover of stones, boulders, or bedrock and a vegetative cover less than 30%. In marine environments the unconsolidated particles smaller than stone is often sand.

There are no estimates of the loss of marine habitats in NPL. Marine intertidal aquatic bed habitats now total about 4800 acres while marine intertidal unconsolidated shore habitats total about 3100 acres (Table 1-A).

Table 1-A. Current and historic estimates of wetlands and deepwater habitats in North Puget Lowlands.

Wetland Class	Current Area	Historical Area	Percent Loss
Marine Intertidal			
Aquatic Bed	4,700	-	-
Unconsolidated Shore	3,100	-	-
Estuarine Subtidal			
Aquatic Bed	200	-	-
Unconsolidated Bottom	24,100	-	-
Estuarine Intertidal			
Aquatic Bed	39,100	-	-
Unconsolidated Shore	14,200	-	-
Emergent	9,700	26,300	63%
Scrub-Shrub	300	12,500	98%
Palustrine			
Scrub-Shrub	2,700	34,300	92%
Forested	2	9,800	≥99%
Emergent	1,500	-	-
Lacustrine		-	-
Aquatic Bed	1,100		

Estuarine

Estuarine systems occur adjacent to marine environments and extend upstream and landward to where ocean-derived salts measure less than 0.5 parts per thousand during periods of average annual flow. Estuarine systems are also divided into subtidal and intertidal subsystems. Two wetland classes in the estuarine subtidal subsystem are included in the plan; 1) aquatic bed, previously defined in the Marine section, and 2) unconsolidated shore, which includes all habitats with substrates having at least 25% cover of particles smaller than stones and a vegetative cover less than 30%. Unconsolidated bottom habitats in estuarine environments have substrates dominated by cobble-gravel, sand, mud, or organic matter. There are also no estimates of the loss of estuarine subtidal habitats in NPL. Estuarine subtidal aquatic bed habitats total less than 300 acres, while estuarine subtidal unconsolidated bottom habitats total nearly 37,000 acres (Table 1-A).

The plan also includes four wetland classes in the estuarine intertidal subsystem; 1) aquatic bed, 2) unconsolidated, 3) emergent, and 4) scrub shrub. Aquatic bed habitats total about 39,000 acres (Table 1-A). While aquatic bed habitats in both estuarine and marine environments may be dominated by eelgrass (*Zostera marina*)**,** most eelgrass is restricted to estuarine areas (Phillips 1984). Eelgrass beds provide an important food source for some priority bird species including brant and wigeon (McRoy and Helfferich 1980, Lovvorn and Baldwin 1996). They also support mollusks, crustaceans, and soft bodied invertebrate species that are eaten by diving ducks and sea ducks and provide spawning habitat for pacific herring (Phillips 1984). Because herring spawn provides an important food source for spring staging scoters, a decline in Pacific herring may have contributed to a decline in scoter numbers.

Eelgrass meadows in Puget Sound are formed within the lower intertidal to shallow subtidal zones from about + 1m to – 5m relative to mean lower low water (MLLW), where MLLW is defined as the average of the lowest water level each day (Bulthuis 1994, Thom et al. 1998). The Submerged Vegetation Monitoring Project (SVMP) being conducted by the Washington State Department of Natural Resources estimates 49,000 acres of eelgrass in Puget Sound. Eelgrass coverage for NPL is tentative because the SVMP sampling design makes regional estimates difficult. However 60% or 30,000 acres of all Puget Sound eelgrass is believed to occur in NPL (Peter Dowty pers. comm.). Since marine and estuarine aquatic bed habitats total about 44,000 acres, most of these aquatic bed habitats probably contain eelgrass (Table 1-A).
The NWI estimates that 85% of these aquatic bed habitats occur in the estuarine intertidal subsystem. However, eelgrass meadows are widely distributed in both the lower intertidal and shallow subtidal zones and some shallow estuarine subtidal habitats may have been incorrectly classified as intertidal.

There are no NPL wide estimates of eelgrass loss since Euro-American settlement, though dredging, filling, and changes in water quality from agriculture, forestry, and development have undoubtedly caused some declines (Phillips 1984). Monitoring of eelgrass beds in Puget Sound over the past 5 years indicates that the overall area of eelgrass is now stable, although there have been local declines in plant coverage (Dowty et al. 2005). Eelgrass beds were also inventoried in Padilla, Samish, and Fidalgo Bays in 1990 and 1996 but no trend was evident in those areas (Pacific Flyway Council 2002).

Estuarine intertidal unconsolidated shore habitats in NPL total about 14,000 acres, and there are no loss estimates for this habitat type. Both unconsolidated shore and unconsolidated bottom habitats in marine and estuarine environments support bottom-dwelling animals such as mollusks and crustaceans that provide important food resources for diving ducks and sea-ducks. Unconsolidated bottom and unconsolidated shore habitats that are regularly exposed by the tides may also be important for shorebirds and some species of dabbling ducks.

Estuarine intertidal emergent wetlands, often referred to as salt or brackish marshes, are regularly inundated by tides and are dominated by herbaceous perennial plant species. Estuarine intertidal scrub shrub wetlands lie inland of salt and brackish marshes and are also tidally influenced, although they are dominated by woody vegetation less than 6 m tall. The historic and current distribution of estuarine intertidal emergent and estuarine intertidal scrub shrub wetlands has been described by Collins and Sheikh (2005). They estimate that estuarine emergent wetlands at the time of Euro-American settlement totaled over 26,000 acres in NPL, while nearly 13,000 acres estuarine scrub shrub habitat was present. These estimates indicate that estuarine emergent wetlands have declined by over 60%, and now total about 9,700 acre. Estuarine scrub-shrub habitat has virtually disappeared since settlement, with loss rates nearing 98% (Table 1-A). By 1915, diking in the Skagit-Samish and Stillaguamish River deltas had converted many of these wetlands to agriculture (Collins 2000). Estuarine scrub shrub wetlands were particularly vulnerable to loss as they were easier to clear than forested wetlands and easier to drain and dike than the lower elevation estuarine emergent habitats.

Palustrine

The palustrine system includes all non-tidal wetlands dominated by trees, shrubs, or herbaceous plants; all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 5 parts per thousand; and wetlands lacking such vegetation but which are less than 2 m deep at low water and less than 20 acres in size (Cowardin et al. 1979). Most "freshwater" wetlands included in the plan fall within the palustrine system and many palustrine wetlands in NPL occur in the floodplains of major river valleys. There are no subsystems in the palustrine classification, but the plan includes three palustrine wetland classes; 1) emergent, 2) scrub-shrub, and 3) forested. The emergent and scrub shrub classes were defined earlier for the estuarine system. Forested wetlands are defined as having woody vegetation 6 m in height or taller. Palustrine emergent habitats now total about 1500 acres, while palustrine scrub shrub wetlands total 2745 acres. Palustrine forested wetlands have largely disappeared from the NPL landscape (Table 1-A).

Collins and Sheikh (2005) provide an indirect estimate of palustrine wetland loss in NPL. The authors modified the Cowardin classification system to create a "riverine tidal" category that includes freshwater wetlands where tidal backwater augments flooding. For example, floodplain wetlands that are flooded in part because of tidal backwater would be included in this riverine tidal category – although most of these wetlands would be classified as palustrine under strict interpretation of the Cowardin system , since they are freshwater habitats dominated by tree, shrub, and herbaceous plant species. Prior to Euro-American settlement there were nearly 24,000 acres of riverine tidal wetlands in NPL. Today, less than 2000 acres of these wetlands remains (Collins and Sheikh 2005).

If changes in riverine tidal wetlands provide an index to palustrine wetland loss, it can be assumed that palustrine wetland loss exceeds 90%. This loss rate was applied to palustrine scrub-shrub wetlands to estimate the amount of scrub shrub habitat that existed prior to Euro-American settlement (Table 1-A). Palustrine forested appear to be largely gone from the NPL landscape, and the loss rate may approach 100%. Prior to settlement, the ratio of palustrine scrub shrub to palustrine forested habitats was about 3.5 to 1 (Collins 2000). This ratio was used in combination with the pre-settlement estimate of palustrine scrub shrub wetlands to derive a historical estimate for palustrine forested habitats (Table 1-A).

It was not possible to estimate the amount of palustrine emergent wetlands that existed prior to settlement since most descriptions of the historic wetland complex make little mention of this habitat type. This may be an artifact of the Cowardin system where wetland classes are distinguished on the basis of the life form of the plants that constitute the uppermost layer of vegetation, and that possess an areal coverage of 30% or greater. Many of

NPL's historic scrub-shrub wetlands may have contained a palustrine emergent component, but because they had shrub coverage of 30% or more this automatically qualified them as scrub-shrub. However, they may have contained large tracts of herbaceous plant species typical of a palustrine emergent marsh. An article in the Snohomish Northern Star (April 14, 1877) that describes the French Creek Marsh lends support to this idea. At the time, the French Creek Marsh was one of the largest freshwater wetlands in NPL.

"*It is nearly cut in half by a swath of spruce and cedar timber…The part below this belt, called the lower marsh ….is splendid pasture land in the summer and fall. It is overflowed by freshets in winter and spring…The upper marsh is beaver meadow, covered with grass, hardhack and tea brush with no timber of any size.*"

The "lower marsh" is described as a pasture, implying an abundance of herbaceous plants suitable for grazing. The other half of the French Creek Marsh is classic scrub shrub, hardhack and tea brush being common shrub species. If these shrubs provide at least 30% areal coverage, then the entire French Creek marsh would be categorized as scrub-shrub. The term "lower marsh" suggests palustrine emergent habitats occurred at the site's lower elevations, which may have contained water for longer periods of time and discouraged shrub establishment.

Lacustrine

The lacustrine system includes wetlands greater than 2 m deep at low water and greater than 8 ha (20 acres) in size and is divided into limnetic and littoral subsystems. Only wetlands in the littoral subsystem are included in the plan, because limnetic habitats are usually too deep to be of value to wetland dependent birds. Although the limnetic subsystem contains six classes, only the aquatic bed class is included here (Figure 7). The NWI estimates that there 1,110 acres of lacustrine aquatic bed wetlands in NPL (Table 1-A). Pre-settlement estimates of lacustrine aquatic bed habitats are lacking, but their greater water depth may have made them more difficult to drain than other wetland types.

Appendix II. TRUEMET Modeling

Background of TRUEMET Model

Joint Ventures have been encouraged to develop biological models that explicitly link bird population objectives to habitat objectives, and to undertake a rigorous analysis of habitat carrying capacity based on these population-habitat models (NAWMP Assessment Steering Committee 2007). The bioenergetic model TRUEMET (CVJV 2006) was used to

evaluate current habitat conditions for priority waterfowl species and to inform future habitat objectives. The model provides an estimate of population food energy demand and food energy supplies for specified time periods. Population energy demand is a function of period specific population objectives and the daily energy requirement of individual birds. Population energy supply is a function of the foraging habitats available and the biomass and nutritional quality of foods contained in these habitats. A comparison of energy supply vs. energy needs provides a measure of carrying capacity relative to bird population objectives.

The results produced by TRUEMET are a function of model structure and parameter inputs; thus, there are two types of error inherent in any modeling exercise, conceptual (theoretical assumptions used to build the model) and empirical (the availability, precision and accuracy of data used for model inputs). Model structure was determined by the set of rules that dictated how birds foraged. Assumptions were: 1) birds were ideal free foragers (Fretwell 1972) and were not prevented from accessing food resources due to interference competition; 2) birds switched to alternate foods when preferred foods were depleted below some foraging threshold; 3) the functional relationships that determined population energy demand and population food energy supplies were linear; and 4) that there was no cost associated with traveling between foraging patches. In some cases, empirical work has shown these assumptions to be false (e.g., Nolet et al. 2006); however, in other cases our assumptions are valid (Arzel et al. 2007, Goss-Custard et al. 2003). Additional studies of waterfowl foraging ecology would either improve model structure of confirm the validity of the daily ration approach.

Although the model can be used to evaluate the carrying capacity of existing landscapes, it can also be used to predict how changes in policy, land use, or habitat programs might impact priority bird species. There are six explicit inputs required for each model run:

1. Time periods being modeled.
2. Waterfowl population objectives.
3. Waterfowl daily energy requirements
4. Amount of each habitat type available in each time period
5. The biomass of food in each habitat type on day one
6. The nutritional quality of each food type.

Time Periods Being Modeled

Within TRUEMET the user must first define the length of the non-breeding period (e.g. October to April). The non-breeding period can then be sub-divided into as may time segments as desired. For example, population energy demand vs. energy supply may be modeled on a daily, weekly, or monthly basis within the larger non-breeding period. The length of these time segments is usually determined by data restrictions. Modeling energy demand vs. supply on a bi-weekly or monthly basis is most common.

Waterfowl Population Objectives

Waterfowl population objectives used in TRUEMET are specific to each time segment (e.g. the month of October). Ideally, these time specific population objectives are derived from the North American Waterfowl Management Plan (NAWMP; NAWMP Plan Committee 2012).

Waterfowl Daily Energy Requirements

Within TRUEMET the user may sub-divide waterfowl into separate foraging guilds that have access to specific foraging habitats. For example, population objectives for each dabbling duck species may be combined into a single "dabbling duck" guild. TRUEMET requires an estimate of the daily energy requirement of the average bird in each foraging guild. To estimate the daily energy requirement of this average bird a resting metabolic rate (RMR) is calculated using the following equation from Miller and Eadie (2006), where RMR is multiplied by a factor of three to account for energy costs of free living:

$$\text{RMR (kJ/day)} = 433 * (\text{body mass in kg})^{0.785}$$

Body mass is equal to the average body mass of birds in a foraging guild.

Habitat Availability and Biomass and Nutritional Quality of Foods

TRUEMET requires information on the availability of waterfowl habitat, the biomass of foods in those habitats, and the nutritional quality of those foods. Habitat availability is a function of habitat area (e.g. acres) and the ability of waterfowl to access foods produced in a habitat type. For example, managed wetlands may total 500 acres but these habitats may only become available after October 1 when they are intentionally flooded.

Food biomass estimates are typically obtained by local sampling or from published sources. However, waterfowl abandon feeding in habitats before all food is exhausted because at some point the costs of continuing to forage on a diminishing resource exceeds energy gained; this value is called the giving-up-density or foraging threshold (Nolet et al. 2006). For example, mallards feeding in dry fields in Texas reduced corn densities to 13 lbs / acre before abandoning fields (Baldassare and Bolen 1984). Consequently, food biomass estimates are usually adjusted by subtracting published estimates of giving up densities. Although waterfowl carrying capacity is strongly dependent on food biomass, the energy or calories provided by these foods is also important. True metabolizable energy or TME provides a measure of the energy waterfowl are able to extract from foods. Published TME estimates are available for many important waterfowl foods.

NPL Landscape Carrying Capacity Analyses

Time Periods being Modeled

This plan addresses the biological needs of priority bird species during the non-breeding period. Although the PCJV generally defines the non-breeding period as September through May, it does differ by species or bird group (Table 2-A). For example, the non-breeding period for dabbling ducks is defined as September 1 to April 30, while the non-breeding period for brant is December 1 to May 31. All bird energy needs were modeled on a monthly basis.

Population Objectives by Time Period

Time-specific population objectives for all bird groups / priority species are presented in Table 3-A. A description of how these population objectives were established can be found in the Biological Planning Section.

Daily Bird Energy Requirements

The daily energy requirements of for priority species/bird groups are presented in Table 4-A. For all species in the dabbling duck group the average body mass of adult male and female birds was used (Bellrose 1980), and a balanced sex ratio assumed. A weighted dabbling duck body mass was calculated from the relative contribution that each species made to the overall dabbling duck objective. Estimates of BMR for brant, snow geese, and swans were also based on the average body mass of adult male and female birds and assumed a balanced sex ratio (Bellrose 1980).

Habitat Availability and Biomass and Nutritional Quality of Foods – Wetlands

Tidal and non-tidal wetlands were described in Appendix I. Although all these habitats provide important wetland functions, not all wetlands provide significant food resources and these classes were excluded from carrying capacity analyses. Area estimates for wetland classes included in the analyses were obtained from the National Wetlands Inventory (NWI) or were based on more recent studies (Table 5-A).

Habitats that contain eelgrass provide critical foraging habitat for many bird species. Most marine and estuarine aquatic bed habitats probably contain some eelgrass and together these classes total about 44,000 acres in NPL. However, a recent estimate of 30,100 acres of eelgrass provided by Washington’s Submerged Vegetation Monitoring Project was used (P. Dowty pers. comm.). All eelgrass was assumed to be available in all time periods and the biomass of eelgrass leaves assumed to average 460 lbs/acre or 511 kg/ha based on sampling in nearby Boundary Bay D. Buffet pers. comm.) The TME of eelgrass leaves is 1.78 kcal/g (Lovvorn and Baldwin 1996; Table 5-A).

Estuarine intertidal emergent wetlands (salt and brackish marshes) total about 9700 acres, and are assumed to be available in all time periods. Recent work indicates that seed production in these habitats only averages about 22 lbs/acre or 25 kg/ha (B. Dugger pers. comm.). TME values are lacking for seeds produced in estuarine habitats. A TME value of 2.5 kcal/g is recommended for seeds produced in palustrine emergent wetlands (Checkett et al. 2002), and this value was applied to estuarine habitats (Table 5-A).

Table 2-A. Time periods modeled for each priority species/bird group.

Priority Species / Bird Group	Time Period Modeled
Dabbling Ducks	September - April
Brant	November - May
Wrangle Island Snow Geese	October - April
Swans	November - March

Table 3-A. Time specific population objectives for priority species/bird groups.

Month	Dabbling Ducks	Brant	Snow Geese	Swans
September	100,911	0	0	0
October	201,823	0	19,366	0
November	423,052	5,600	30,340	4,441
December	551,132	18,160	40,700	9,011
January	388,121	20,000	62,900	9,011
February	368,715	20,000	71,040	9,011
March	314,378	24,000	62,160	4,506
April	221,229	33,440	25,974	0
May	0	18,400	0	0

Table 4-A. Daily energy requirements (kcal) for priority species/bird groups.

	Dabbling Ducks	Brant	Snow Geese	Swans
Daily Energy Requirement (kcal)	312[a]	360	614	1,106

[a] Based on a weighted body mass that reflects the relative contribution that mallards, wigeon, and pintails make to the NPL dabbling duck population.

Table 5-A. Wetland habitats included in the Pacific Coast Joint Ventures’s carrying capacity analyses.

Wetland Habitat	Area (acres)	Food Density (lbs/acre)	TME (kcal/g)
Eelgrass Beds[a]	30,100	460[b]	1.8
Estuarine IT Emergent	9,700	22[c]	2.5
Palustrine Emergent	1,500	113[d]	2.5

[a] Includes Marine IT Aquatic Bed, Estuarine ST Aquatic Bed, and Estuarine IT,Aquatic Bed,[b] Incorporates a giving – up – density of 44 lbs/acre (Reinecke et al. 1989), [c] No giving – up – density of applied , [b] Incorporates a giving – up – density of 30 lbs/acre (Naylor 2002), IT - Intertidal

Palustrine emergent wetlands total about 1500 acres and are assumed to be available in all time periods (Table 5-A). In some areas palustrine emergent wetlands are managed as seasonal habitats that are annually drawn down and reflooded (e.g. the Central Valley of California). This type of management encourages the growth of annual plant species that produce an abundance of seeds. Few palustrine emergent wetlands in NPL are managed as seasonal wetlands. Instead, these habitats contain water year round and are dominated by perennial plant species not associated with high seed production. Seed production estimates for these habitats are lacking. Seed production in seasonally managed palustrine emergent wetlands averaged 566 lbs/acre in the Central Valley (Naylor 2002). It was assumed that seed production in palustrine emergent habitats in NPL averaged 20% of this value or 113 lbs/acre and that the TME value of these seeds was 2.5 kcal/g (Checkett et al. 2002). Although palustrine scrub shrub habitats total 2,700 acres in NPL they are believed to provide little foraging value, as they are dominated by woody vegetation.

Habitat Availability and Biomass and Nutritional Quality of Foods - Agriculture

Private farmland in NPL provides over 65,000 acres of agricultural habitats that are important to migrating and wintering waterfowl (Table 6-A). Harvested potatoes fall cover crops, and corn harvested for silage account for most these habitats. Over eleven thousand acres of potatoes are now planted in NPL. Waste potatoes average 708 lbs/acre or 788 kg/ha (D. Buffet pers. comm.), and have a TME value of 4.0 kcal/g (Dugger et al. 2008). Potato harvest begins in early August and is complete by mid to late December with 50% of the crop harvested by mid-October. Fall cover crops average nearly 1600 lbs/acre or 1774 kg/ha (D. Buffet pers. comm) and provide 2.4 kcal / g in TME (Petrie et al. 1998). Approximately 27,000 acres of cover crops are now grown in NPL. Cover crops are established on 25% of these acres by mid-October and established on all 27,000 acres by mid-December. Corn grown for silage also totals about 27,000 acres and provides an estimated 22 lbs/acre or 25 kg/ha of waste corn (Baldassare et al. 1983) with a TME value of 3.9 kcal/g. It was assumed that 25% of all silage is harvested by October 1, with the remainder harvested at a constant rate until completion in mid-November.

Table 6-A. Agricultural habitats included in the JV's carrying capacity analyses.

Agricultural Habitat	Area (acres)	Food Density[a] (lbs/acre)	TME (kcal/g)
Harvested Potatoes	11,500	708	4.0
Harvested Silage Corn	27,400	22	3.9
Cover Crops	27,000	1,600	2.4
Unharvested Barley	770	5,700	3.0
Unharvested Corn	385	4,100	3.9

[a] All food density estimates incorporate a giving-up-density of 13 lbs/acre (Baldassare and Bolen 1984)

Agricultural foods are also intentionally grown for waterfowl on both public lands and privately owned hunt clubs. Public lands in NPL provide an estimated 600 acres of unharvested barley and 65 acres of unharvested corn for waterfowl. Private hunt clubs provide approximately 320 acres of unharvested corn and 170 acres of unharvested barley. It's assumed that unharvested barley provides nearly 5700 lbs/acre or 6500 kg/ha and provides 3.0 kcal/g in TME, and that unharvested corn provides over 4100 lbs/acre or 4700 kg/ ha with a TME value of 3.9 kcal/g. Both crops are assumed available by September 1.

Finally, specific assumptions were made about the foraging habitats available to each species or bird group. For example, mallards and pintails have access to most agricultural crops, while brant are restricted to foraging in tidal habitats that support eelgrass (Table 7-A**).** Where species or bird groups overlap in their use of foraging habitats (e.g. wigeon and snow geese both consume cover crops), TRUEMET treats them as exploitive competitors that impact each other's food supply.

Table 7-A. Foraging habitats available to priority species in the TRUEMET model

Foraging Habitat	Mallard	Pintail	Wigeon	Brant	Snow Geese	Swans
Eelgrass [a] Beds			X	X		
Estuarine IT Emergent	X	X				
Palustrine Emergent	X	X				
Harvested Potatoes	X	X			X	X
Harvested Silage Corn	X	X			X	X
Cover Crops	X	X	X		X	X
Unharvested Barley	X	X			X	X
Unharvested Corn	X	X			X	X

[a] Includes Marine IT Aquatic Bed, Estuarine ST Aquatic Bed, and Estuarine IT Aquatic Bed classes
IT - Intertidal
ST- Subtidal

TRUEMET Simulations

PACIFIC BRANT

Scenario # 1: Carrying capacity of native eelgrass for brant where all leaf biomass is available for consumption.

The capacity of native eelgrass to support Pacific brant was modeled from November to May. Brant were assumed to feed exclusively on the leaves of native eelgrass and 100% of all leaf biomass was made available to brant in the TRUEMET model. Other species like wigeon may also consume significant amounts of eelgrass. However, Scenario # 1 did not include wigeon and their possible effects on brant food supplies.

Outcome Scenario # 1**:** Food supplies for brant appear to be well above population needs, if all leaf biomass is available for consumption and the possible effects of wigeon on brant food supplies are discounted (Figure 1-A).

Scenario # 2: Minimum amount of eelgrass needed to meet brant needs

The assumption that all leaf biomass is available to brant is undoubtedly false. Brant prefer the inner leaves of eelgrass and avoid older leaves that are often thickly covered by epiphytes (J. Black pers. comm.). Moreover, some eelgrass may be unavailable because of depth or tide cycles (Moore and Black 2006). To estimate what amount of total leaf biomass must be available to meet brant needs leaf biomass was gradually reduced in the TRUEMET model until food energy supply equaled population energy demand.

Outcome Scenario# 2**:** The food energy needs of brant were still met even when the existing biomass of eelgrass leaves was reduced 80% in the TRUEMET model. This suggests that brant needs can be met if ≥20% of leaf biomass occurs as inner leaves (or leaves palatable to brant), and that these leaves occur in parts of the intertidal and subtidal zones that are accessible to brant.

Scenario # 3: *Incorporating the possible effects of wigeon on brant food supplies where all leaf biomass is available for consumption.*

Significant numbers of wigeon are present in NPL and wigeon often consume leaves of native eelgrass. Accordingly, the possible effects of wigeon on brant food supplies were modeled. In Scenario # 3 wigeon were assumed to meet 100% of their energy needs from eelgrass leaves in all time periods (September to April), and 100% of leaf biomass was available to both species.

Outcome Scenario # 3**:** Brant food supplies appear adequate even when wigeon rely solely on eelgrass, provided100% of leaf biomass is available for consumption (Figure 2-A).

Scenario# 4: *Minimum amount of eelgrass needed to meet brant needs when possible effects of wigeon on brant food supplies included.*

The assumption in Scenario # 3 that all leaf biomass is available to both brant and wigeon is undoubtedly false. To estimate the minimum amount of leaf biomass that must be available to meet brant needs when accounting for the effects of wigeon, leaf biomass in Scenario # 4 was reduced in TRUEMET until eelgrass was no longer able to satisfy brant demand. In this scenario both brant and wigeon met 100% of their food energy needs from eelgrass in all time periods (for wigeon this includes September to April).

***Outcome Scenario # 4*:** Brant food supplies appear adequate if ≥70% of total leaf biomass occurs as inner leaves (or leaves palatable to brant) and these leaves occur in parts of the intertidal and subtidal zones that are accessible to brant and wigeon

***Scenario# 5**: Minimum amount of eelgrass needed to meet brant needs when possible effects of wigeon consumption included (September – November).*

Scenario # 4 suggests that that a very high percentage of leaf biomass (≥70%) must be available if brant are to meet all of their food energy needs from eelgrass. However, wigeon have access to abundant agricultural habitats in NPL (see Scenario # 10). In nearby Boundary Bay wigeon shifted their foraging from eelgrass to agricultural habitats by the end of November (Lovvorn and Baldwin 1996). Scenario # 5 assumes that wigeon rely solely on eelgrass only from September through November and on agricultural foods after November.

***Outcome Scenario # 5*:** Brant food supplies appear adequate if ≥33% of total leaf biomass occurs as inner leaves (or leaves palatable to brant) and that these leaves occur in parts of the intertidal and subtidal zones that are accessible to brant.

Uncertainty about the amount of eelgrass available to brant and the competitive effects of wigeon hindered carrying capacity analyses for brant. Still, only about a third of all eelgrass had to be available to meet brant needs if wigeon rely on eelgrass at levels similar to Boundary Bay. Thus, eelgrass is probably sufficient to support black brant and WHA brant at objective levels. However, a better understanding of eelgrass availability is needed and this should be considered when establishing PCJV research priorities.

DABBLING DUCKS

Previous work by Lovvorn and Baldwin (1996) suggests that prior to December dabbling ducks in nearby Boundary Bay met most of their food energy needs from estuarine intertidal habitats dominated by eelgrass. Although native eelgrass and non-native eelgrass (Zostera japonica) both occur in Boundary Bay, dabbling ducks mostly foraged in non-native eelgrass beds (Lovvorn and Baldwin 1996).

It is unknown whether dabbling ducks in NPL undergo a similar shift in foraging from intertidal to agricultural habitats. If dabbling ducks in NPL rely heavily on intertidal habitats during fall, then consumption of agricultural food sources may be delayed until late fall or early winter. Conversely, NPL dabbling ducks may make little use of intertidal habitats and may begin foraging in agricultural habitats earlier than occurs in Boundary Bay.

Dabbling ducks in Boundary Bay mostly consumed the leaves and rhizomes of the non-native eelgrass Z. japonica. In contrast, birds made little use of native eelgrass. Although estimates of Z. japonica are lacking for NPL, the Submerged Vegetation Monitoring Project (SVMP) detected Z. japonica in 5 of its 25 NPL sites. However, this should be considered a minimum estimate because the SVMP did not sample higher elevations in the intertidal zone where Z. japonica mostly occurs. Sampling of seagrass in Padilla Bay in 1989 recorded about 7200 acres of native eelgrass and 750 acres of Z. japonica, or about 10% of all eelgrass.

A lack of information on the use of intertidal and agricultural habitats by NPL dabbling ducks, as well as information on the abundance of Z. japonica, complicated the analysis of carrying capacity for dabbling ducks. To deal with this uncertainty, the PCJV explored the ability of eelgrass and other intertidal habitats to support dabbling ducks. If these habitats could meet dabbling ducks energy needs for a long period, as appears the case for Boundary Bay, then consumption of foods in non-tidal areas may be delayed. If this is not the case, then the analysis of carrying capacity should assume that birds rely heavily on agricultural and freshwater habitats at an earlier date.

Scenario # 6: The potential for non-native eelgrass (Z. japonica) to support dabbling ducks from early to late fall (September 1 – November 30).

This scenario assumed that the area of Z. japonica in NPL was equal to 10% of the area of native eelgrass based on sampling in Padilla Bay which contains the largest amount of eelgrass of any NPL estuary. Biomass and TME estimates for Z. japonica leaves and rhizomes were obtained from Baldwin and Lovvorn (1996). The contribution that Z. japonica leaves and rhizomes made to the daily energy requirements of dabbling ducks was also estimated from Baldwin and Lovvorn (1994). For example, wigeon in Boundary Bay met 84% of their daily energy needs from the leaves and rhizomes of Z. japonica. From a modeling standpoint it was assumed that the other 16% was met from intertidal foods not included in the carrying capacity analysis (e.g. from japonica seeds or invertebrates for which there was no biomass estimates).

***Outcome Scenario # 6*:** Unlike Boundary Bay, the leaves and rhizomes of Z. japonica do not appear capable of supporting dabbling ducks through late November. Instead, these food resources appear to be depleted prior to October 1 (Figure 3-A).

Scenario # 7: The amount of non-native eelgrass (Z. japonica) needed to support dabbling ducks from early to late fall (September 1 – November 30).

The assumption that japonica abundance is only 10% of native eelgrass is based on 20-year old sampling from Padilla Bay. Between 1970 and 1991 there was a seventeen fold increase in Z. japonica in Boundary Bay (Baldwin and Lovvorn 1994). Thus, the PCJV may be significantly underestimating the amount of non-native eelgrass now present in NPL. As a result, TRUEMET was used to estimate the amount of Z. japonica needed to meet dabbler energy needs from September 1 through November 30. It was assumed that all Z. japonica leaves and rhizomes were available.

***Outcome Scenario # 7*:** It was estimated that 34,000 acres of Z. japonica are needed to meet dabbler needs from September 1 to November 30. This figure exceeds the amount of native eelgrass now present in NPL (30,100 acres).

Scenario # 8: Carrying capacity of estuarine intertidal emergent wetlands (salt and brackish marsh).

Dabbling ducks may rely on tidal habitats other than eelgrass to help meet their food energy needs, including estuarine intertidal emergent wetlands. Within NPL there are nearly 10,000 acres of intertidal emergent wetlands. TRUMET was used to evaluate the capacity of these habitats to support mallards, wigeon, and pintail.

***Outcome Scenario # 8*:** The carrying capacity of these intertidal wetlands for dabbling ducks appears low as food supplies are depleted in less than a month (Figure 4-A). This was not unexpected given the low food density estimated for this habitat type (Table 6-A).

Given the results for Scenario # 8 and the lack of information on Z. japonica and mallard and pintail use of native eelgrass, the PCJV assumed that these two species meet none of their food energy needs from tidal habitats. The Joint Venture recognizes that this is a conservative assumption and overestimates the foraging pressure put on freshwater and agricultural habitats. This assumption *does not diminish the importance of tidal habitats in NPL,* but rather reflects a conservative approach to evaluating carrying capacity. In contrast to mallards and pintails, wigeon are assumed to meet all their food energy needs in September from native and non-native eelgrass. After September wigeon are assumed to rely on agricultural food sources. This is a conservative assumption given the carrying capacity results for brant (see Scenario # 5).

Scenario # 9: Carrying capacity of harvested agricultural lands for mallards and pintails

This scenario examined the capacity of harvested agricultural lands to meet the food energy needs of mallards and pintails. It was assumed that both species forage in harvested potato fields and harvested corn fields (silage), and that snow geese and swans also make use of these foraging habitats (Table 7-A). All agricultural lands included in this Scenario are privately owned and not managed for waterfowl.

Outcome Scenario # 9: Harvested agricultural lands can meet 100% of the food energy needs of mallards and pintails from September 1 through mid-February (Figure 5-A). Within TRUEMET, snow geese have access to cover crops as well as harvested potato and harvested corn fields. If snow geese are mostly relying on cover crops to meet their food energy needs (see Scenario # 13), then TRUEMET may be overestimating the competitive effect of snow geese on mallard and pintail food supplies. If so, harvested agricultural lands may meet the needs of these two duck species beyond mid-February.

Scenario # 10: Carrying capacity of cover crops for wigeon.

This scenario examined the capacity of winter cover crops to meet the food energy needs of wigeon between October 1 and April 30. It's assumed that wigeon are able to meet their food energy needs from native and non-native eelgrass from at least September 1 to September 30. Snow geese and swans are also assumed to forage on winter cover crops and their consumptive effects on this food source are included in the scenario.

***Outcome Scenario # 10*:**

Winter cover crops far exceed the food energy needs of wigeon in all time periods even when the consumptive effects of snow geese and swans are considered (Figure 6-A).

Scenario # 11: Carrying capacity of harvested and unharvested agricultural lands for mallards and pintails

This scenario examined the capacity of harvested agricultural lands and agricultural lands where crops are left standing for waterfowl to meet the food energy needs of mallards and pintails. Agricultural lands where crops are left standing include publicly owned habitats as well as private lands managed for waterfowl hunting. Snow geese and swans were also assumed to forage in both harvested and unharvested agricultural habitats.

***Outcome Scenario # 11*:** Harvested and unharvested agricultural lands together can meet 100% of mallard and pintail food energy needs from September through April (Figure 7-A). However, the surplus of agricultural food is far less than estimated for wigeon (Figure 6-A).

Scenario # 12: Carrying capacity of non-tidal wetlands for mallards and pintails.

This scenario examined the capacity of non-tidal (freshwater wetlands) to meet the food energy needs of mallards and pintails. The freshwater wetlands included in this scenario are all classified as palustrine emergent and total 1500 acres (Table 5-A).

***Outcome Scenario # 12*:** Freshwater wetlands are unable to meet the food energy needs of mallards and pintails beyond October (Figure 8-A). This was not unexpected given the low food density estimated for this habitat type (Table 5-A).

SNOW GEESE

Scenario # 13: Carrying capacity of cover crops for snow geese.

This scenario examined the capacity of winter cover crops to meet the food energy needs of snow geese between October 1 and April 30. Wigeon and swans are also assumed to forage on winter cover crops and their effects on this food source are included in the scenario (Table 7-A).

Outcome Scenario # 13**:** Winter cover crops far exceed the food energy needs of snow geese in all time periods (Figure 9-A).

Scenario # 14: Carrying capacity of harvested and unharvested agricultural lands for snow geese, including winter cover crops.

This scenario examined the capacity of harvested agricultural lands and agricultural lands where crops are left standing for waterfowl to meet the food energy needs of snow geese. Agricultural lands where crops are left standing include publicly owned habitats as well as private lands managed for waterfowl hunting. Mallards, pintails, and swans were also assumed to forage in both harvested and unharvested agricultural habitats (Table 7-A).

Outcome Scenario # 14: Harvested and unharvested agricultural lands together can meet 100% of snow goose food energy needs from September through April with a large food surplus remaining (Figure 10-A). Most of this surplus is attributed to winter cover crops (see Scenario # 13).

SWANS

Scenario # 15: Carrying capacity of harvested and unharvested agricultural lands for swans, including winter cover crops.

This scenario examined the capacity of harvested agricultural lands and agricultural lands where crops are left standing for waterfowl to meet the food energy needs of swans. Agricultural lands where crops are left standing include publicly owned habitats as well as private lands managed for waterfowl hunting. Mallards, pintails, and snow geese were also assumed to forage in both harvested and unharvested agricultural habitats (Table 7-A).

Outcome Scenario # 15**:** Harvested and unharvested agricultural lands together can meet 100% of swan energy needs from November through March, with a large food surplus remaining (Figure 11-A). Most of this surplus is attributed to winter cover crops (see Scenario # 13).

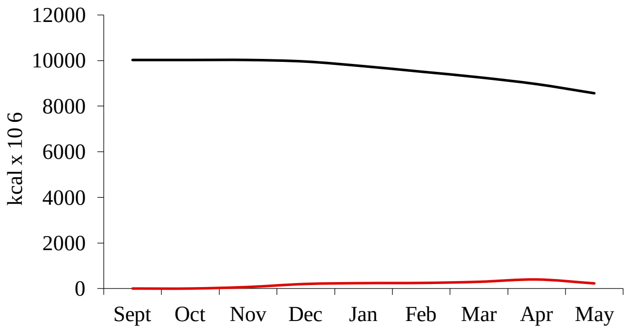

Figure 1-A. Scenario # 1: Brant food energy supply (black) vs. population energy demand (red).

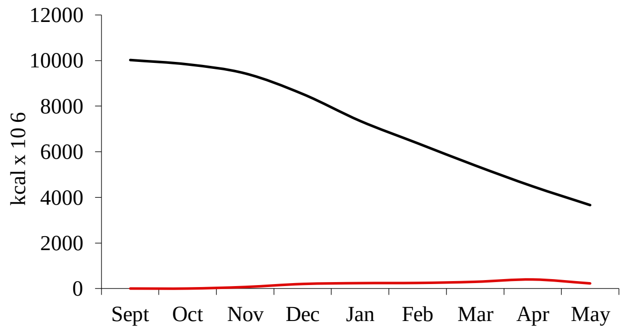

Figure 2-A. Scenario # 3: Brant food energy supply (black) vs. population energy demand (red).

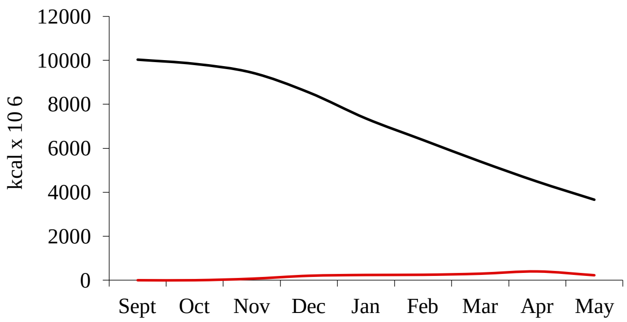

Figure 13-A. Scenario # 6: Dabbling duck food energy supply (black) vs. population energy demand (red).

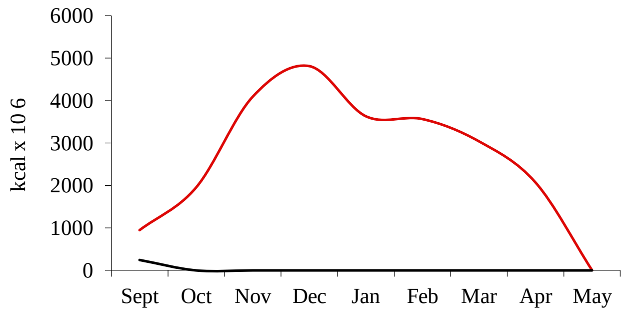

Figure 4-A. Scenario # 8: Dabbling Duck food energy supply (black) vs. population energy demand (red).

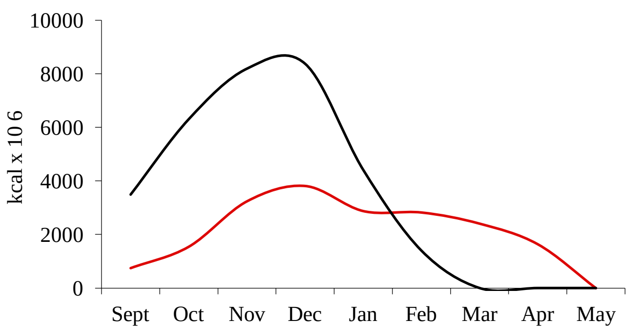

Figure 5-A. Scenario # 9: Mallard and pintail food energy supply (black) vs. population energy demand (red).

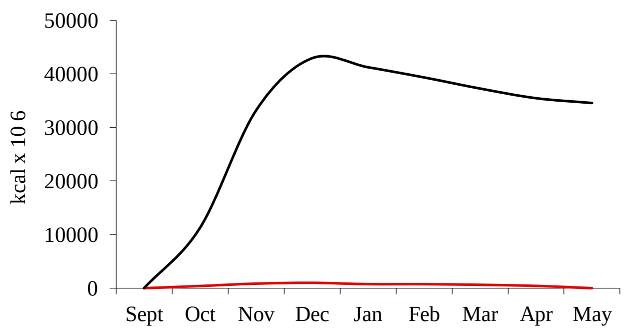

Figure 6-A. Scenario # 10: Wigeon food energy supply (black) vs. population energy demand (red).

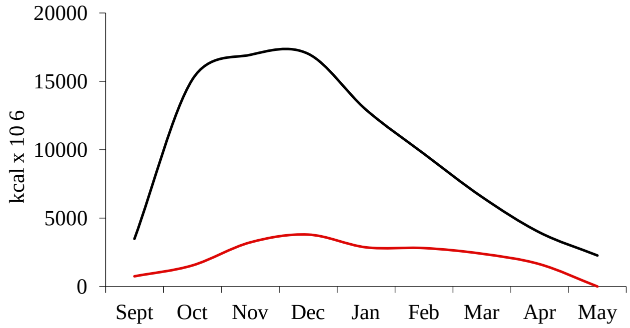

Figure 7-A. Scenario # 11: Mallard and pintail food energy supply (black) vs. population energy demand (red).

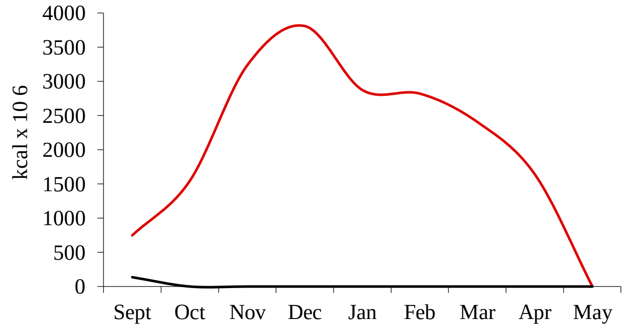

Figure 8-A. Scenario # 12: Mallard and pintail food energy supply (black) vs. population energy demand (red).

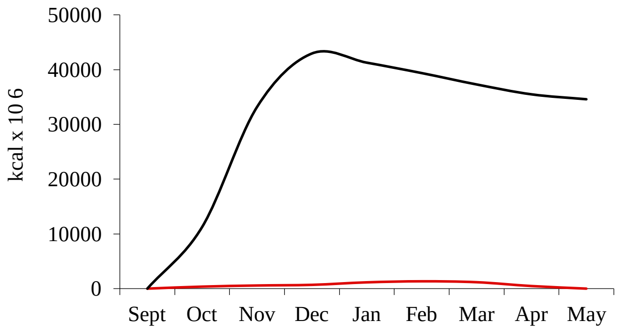

Figure 9-A. Scenario # 13: Snow geese food energy supply (black) vs. population energy demand (red).

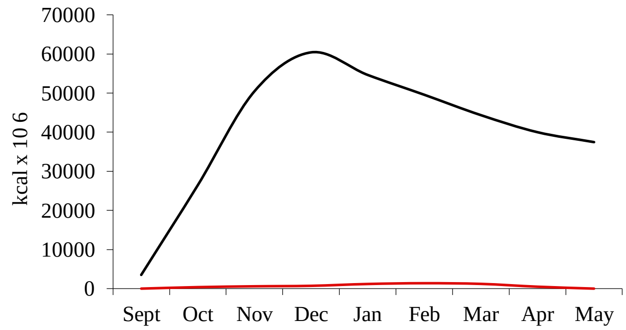

Figure 10-A. Scenario # 14: Snow geese food energy supply (black) vs. population energy demand (red).

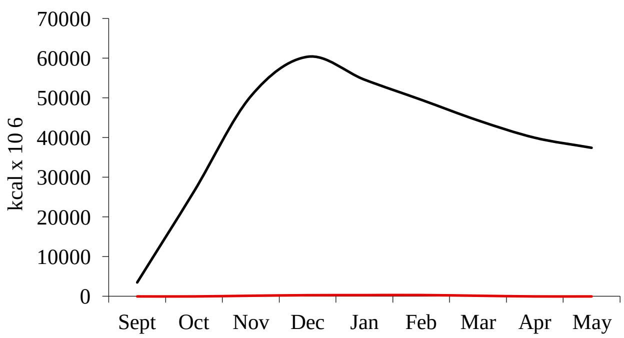

Figure 11-A. Scenario # 15: Swan food energy supply (black) vs. population energy demand (red).

Appendix III. Washington Department of Fish and Wildlife Aerial Surveys

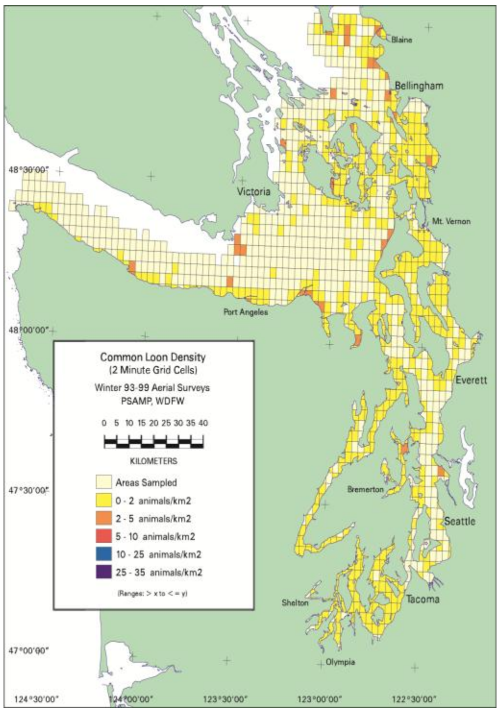

Figure 12-A. Common Loon density in Puget Sound as determined from Washington Department of Fish and Wildlife aerial surveys

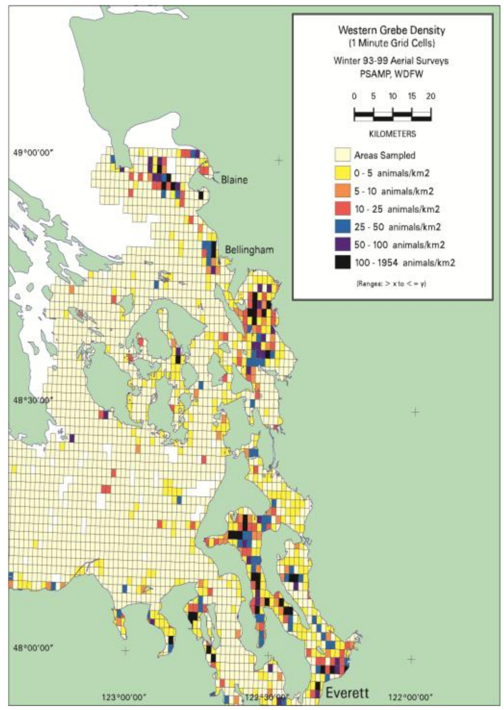

Figure 13-A. Western Grebe density in Puget Sound as determined from WDFW aerial surveys.

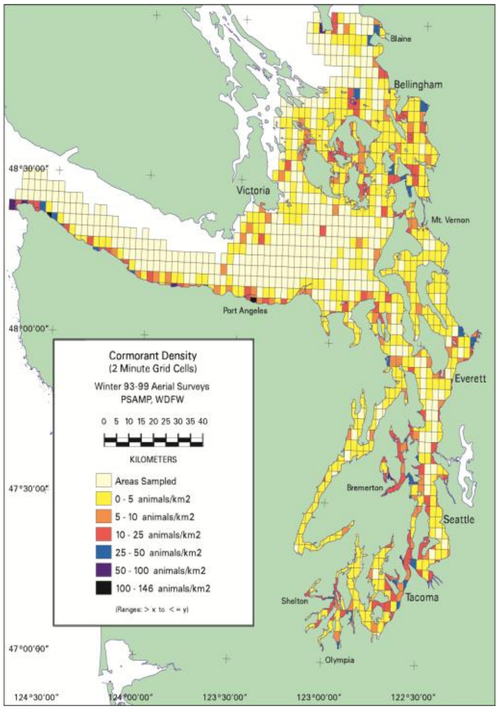

Figure 14-A. Cormorant density in Puget Sound as determined from WDFW aerial surveys.

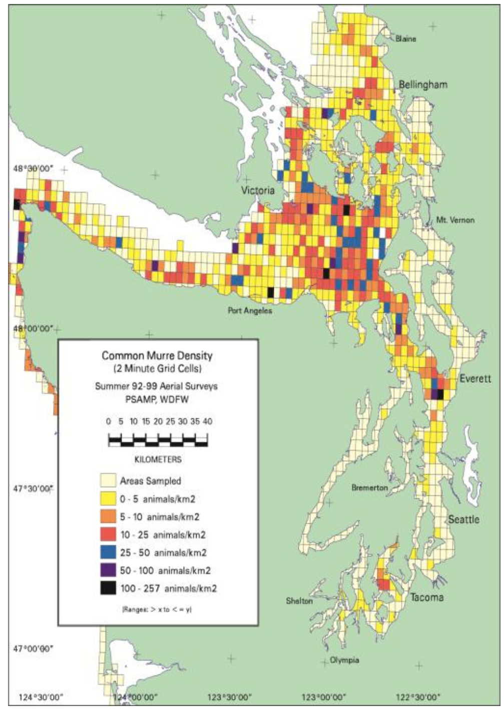

Figure 16-A. Common Murre density in Puget Sound as determined from WDFW aerial surveys.

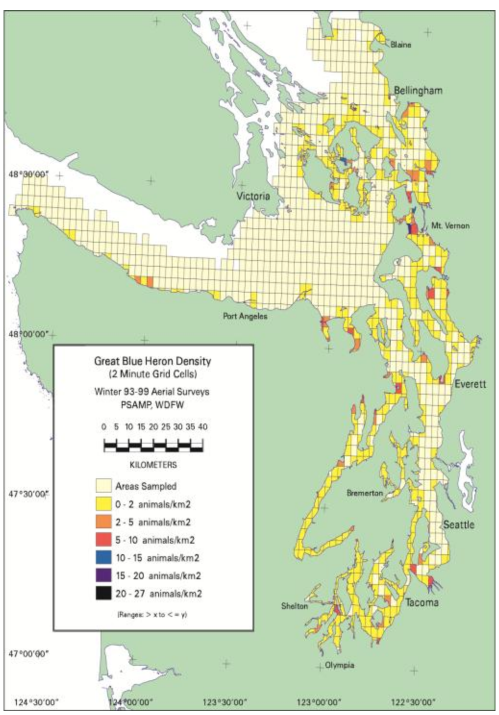

Figure 15-A. Great Blue Heron density in Puget Sound as determined from WDFW aerial surveys.

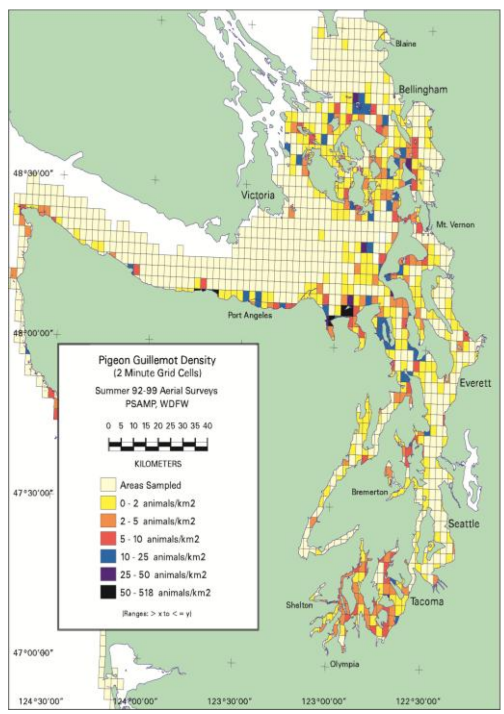

Figure 17-A. Pigeon Guillemont density in Puget Sound as determined from WDFW aerial surveys.

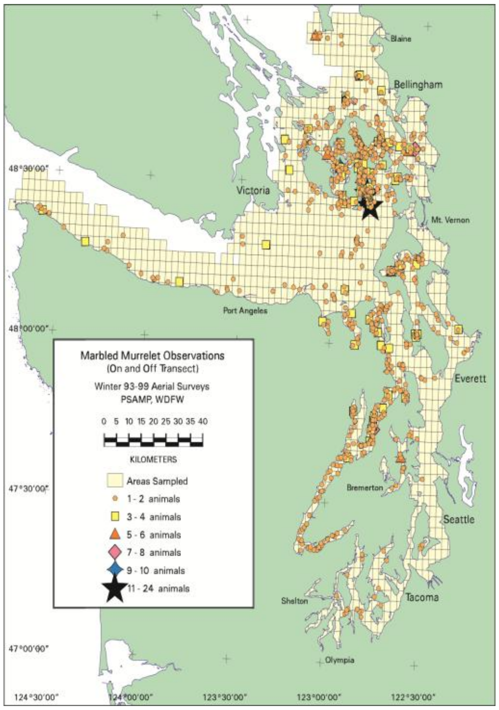

Figure 18-A. Marbled Murrelet observations in Puget Sound as determined from WDFW aerial surveys.

Appendix IV. Sea Level Rise

The National Wildlife Federation (NWF) has examined the effects of sea level rise (SLR) on coastal habitats in the Pacific Northwest including those in NPL using the Sea Level Affecting Marshes Model or SLAMM (Glick et al. 2007). The NWF report predicts changes in Pacific Coast habitats by 2100 for SLR scenarios of 0.39 m, 0.69 m, 1.0 m and 1.5 m. Eleven study sites along the Oregon and Washington coasts were included in the report. Four of these study sites correspond to NPL (Sites 1, 2, 3, and 4**).** Habitat types in the NWF report are generally based on the Cowardin et al. (1979) system for classifying wetlands and deepwater habitats. This same classification system was used to characterize NPL's major wetland classes.

Although the NWF report includes seventeen habitat types many of these habitats are similar in terms of elevation, salinity, and other ecological characteristics. In other words the report tended to split habitat types as opposed to grouping them. Predicting habitat change using such a fine classification scale seems questionable given uncertainties about SLR and SLAMM itself. For conservation planning purposes it may be better to combine these habitat types into broader categories.

Twelve Cowardin et al. (1979) wetland classes occur in NPL (see "Conservation Design" section). Eight of these Cowardin classes are included in the NWF report. To evaluate the impact of sea level rise, NPL's twelve wetland classes were combined into five "nearshore" zones arranged along a gradient of increasing elevation and decreasing salinity.
The first nearshore zone was designated "low tidal" and includes six wetland classes;
1) marine intertidal unconsolidated shore, 2) marine intertidal aquatic bed, 3) estuarine subtidal unconsolidated bottom, 4) estuarine subtidal aquatic bed, 5) estuarine intertidal unconsolidated shore and 6) estuarine intertidal aquatic bed. Two of these classes, marine intertidal unconsolidated shore and estuarine intertidal unconsolidated shore, are included in the NWF report (Table 20).

The NWF report divides estuarine intertidal emergent wetlands into saltmarsh and brackish marsh habitats based on frequency of tidal flooding. The second nearshore zone "saltmarsh" includes all estuarine intertidal emergent habitats that were classified as saltmarsh in the NWF report. "Transitional marshes" make up the third nearshore zone and include all estuarine intertidal emergent wetlands that were classified as brackish marsh and all estuarine intertidal scrub shrub habitats (Table 20). The fourth nearshore zone, "freshwater tidal", includes palustrine forested, palustrine scrub-shrub, and palustrine emergent wetlands that are associated with a tidal modifier in the Cowardin classification system. These wetlands do not meet the salinity requirements of estuarine habitats but are still moderately influenced by tidal flow
(e.g. backwater flooding during high tide events). The final nearshore zone, "freshwater non-tidal" includes palustrine forested, palustrine scrub-shrub, palustrine emergent, and lacustrine aquatic bed wetlands that are not subject to tidal influence (Table 20). Forecasts of habitat change for wetland classes in each nearshore zone were obtained from the NWF report for SLR scenarios of by 0.39 m, 0.69 m, 1.0 m and 1.5 m between now and 2100. These forecasts were available at twenty-five year intervals.

SLAMM results are partially dependent on elevation data. The NWF report relied on low resolution NED data to forecast habitat change. Two of the report's four study sites, Sites 1 and Site 2, were reanalyzed in 2009 using high resolution LIDAR data. Habitat change forecasts were compared using LIDAR and NED data for the low tidal, freshwater tidal, and freshwater non-tidal nearshore zones to determine if these forecasts were strongly dependant on elevation data type. Within the NWF report much of the existing saltmarsh was mistakenly classified as brackish marsh for Sites 1 – 4 (J. Clough pers. comm.). This error was corrected in the 2009 analysis of Sites 1 and 2. As a result, the JV relied exclusively on the 2009 analysis for forecasting the effects of SLR on the saltmarsh and transitional marsh categories. This obviously precludes any comparison of NED and LIDAR data for these two zones and restricts the results for saltmarsh and transitional marsh to Sites 1 and 2. Fortunately over 80% of the existing wetlands in NPL that occur in these two nearshore zones are found in Sites 1 and 2.

Low Tidal

The NWF report provides sea level rise predictions for only two classes in the JV's low tidal category; marine intertidal unconsolidated shore, and estuarine intertidal unconsolidated shore (Table 20). Although these two wetland classes total nearly 12,700 acres in the NWF report, 98% of these acres are estuarine intertidal unconsolidated shore habitats. Moreover, 80% of these estuarine intertidal habitats occur in Site 2. Site 2 corresponds to an area of NPL which contains most of the region's coastal wetland habitat. Thus, any change in low tidal habitat predicted by the NWF report is mostly driven by changes in estuarine intertidal unconsolidated shore habitats in Site 2.

Low tidal habitats were predicted to decline by 2100 under all SLR scenarios from 7% to 35%. However, the amount of decline and the temporal pattern of loss differed by scenario (Figure 19-A). The loss of low tidal habitat was greater for moderate SLR scenarios of 0.39 m and 0.69 m. Although low tidal habitats experience a steep decline between now and 2025 for the 1.0 m and 1.5 m scenarios these habitats undergo some recovery by 2100. In contrast, low tidal habitats initially increase in the 0.39 m and 0.69 m SLR scenarios before declining.

NED and LIDAR data both predicted a loss of low tidal habitat. However, the amount and pattern of decline differed. The loss of low tidal habitat by 2100 increased with increasing SLR from 14% at 0.39 m to 25% at 1.5 m using LIDAR (Figure 20-A). In contrast, the loss of low tidal habitat was greater for the moderate SLR scenarios when NED data were used (Figure 19-A). For LIDAR the pattern of decline was similar across scenarios with low tidal habitats declining between now and 2025 then experiencing little change between 2025 and 2050. Low tidal habitats then resumed their decline between 2050 and 2100 (Figure 20-A). In contrast, the pattern of decline varied widely among SLR scenarios when NED data were used (Figure 19-A).

The estuarine intertidal aquatic bed class is an important habitat type in the low tidal zone because it supports eelgrass. Unfortunately, the NWF report does not forecast changes to this habitat type. Estuarine intertidal aquatic bed and estuarine intertidal unconsolidated shore habitats do occur in the same Cowardin subsystem. Forecasted declines in unconsolidated shore may indicate a decline in aquatic bed habitats because the two classes occur at similar tidal elevations. However, eelgrass distribution in subtidal and intertidal environments is governed by multiple factors and the impacts of SLR on intertidal unconsolidated shore habitats don't necessarily translate to eelgrass.

Water depth strongly influences eelgrass distribution. Eelgrass is limited in the upper part of the low tidal zone because of drying out at low tides. Eelgrass achieves its highest density at moderate water depths then declines in deeper water as light penetration is reduced. The relationship between water depth and eelgrass density provides insight into the possible effects of SLR. Parts of the low tidal zone that support eelgrass at the limit of its depth tolerance may become devoid of eelgrass as sea level increases. Areas of the low tidal zone that now support the highest density of eelgrass may experience a decline in eelgrass because of increasing water depths and reduced light penetration. In contrast, upper parts of the low tidal zone that support low densities of eelgrass may see an increase in plant density as water depths become more favorable.

Net changes in eelgrass from SLR may depend on upper portions of the nearshore zone that are available for eelgrass colonization. Factors controlling the "resiliency" of eelgrass to SLR were demonstrated in a recent study in Padilla Bay, Washington (Kairis and Rybcyk 2010). The authors examined if eelgrass meadows in Padilla Bay were at risk of submergence from SLR. Eelgrass was predicted to increase under moderate SLR scenarios as eelgrass migrated from the center of the Bay shoreward. Eelgrass was forecasted to increase because Padilla Bay contains large amounts of nearshore habitat that is favorable for eelgrass colonization as sea levels rise. *Although the study was specific to Padilla Bay, it demonstrates that the resiliency of coastal wetland habitat to SLR is strongly dependent on the opportunity for these habitats to migrate upslope*.

Saltmarsh

Saltmarsh habitats are predicted to remain stable or increase slightly from now until 2100 for sea level rise scenarios between 0.39 m and 1.0 m. Significant declines in saltmarsh (i.e. 20%) were only forecast for the 1.5 m SLR scenario. For all scenarios the amount of saltmarsh increased between now and 2050 before declining (Figure 21-A).

Transitional Marsh

The JV's transitional marsh category includes estuarine intertidal emergent wetlands that were categorized as "brackish marsh" in the NWF report and all estuarine intertidal scrub shrub wetlands (Table 20). Transitional marsh habitat was predicted to steadily increase from now until 2100 for all SLR scenarios (Figure 22-A).

Freshwater Tidal

Freshwater tidal habitats were predicted to decline by about 65% regardless of the SLR scenario. Most of this decline occurred within the first twenty five years (Figure 23-A). LIDAR based results also indicated a decline in freshwater tidal habitats. However, this decline was greater for higher levels of SLR and ranged from an 18% loss at 0.39 m to a 41% loss at 1.5 m (Figure 24-A).

Freshwater

Forecasted declines in freshwater habitats were similar for all SLR scenarios and ranged between 8% and 15% (Figure 25-A). Forecasted declines in freshwater habitats were also similar for all SLR scenarios when LIDAR data were used though these forecasts suggested a decline of only 4% to 6% (Figure 26-A).

In summary, SLAMM predicted that low tidal and freshwater tidal habitats will experience significant declines for most SLR scenarios while freshwater habitats would experience modest declines. Saltmarsh was forecasted to show little change except for all but the highest SLR scenario, while transitional marsh was projected to significantly increase for all scenarios.
Both LIDAR and NED based results predicted a decline in low tidal, freshwater tidal, and freshwater habitats. However, there were differences in the magnitude and timing of habitat loss between the two elevation data types with LIDAR generally predicting a lower rate of habitat loss.

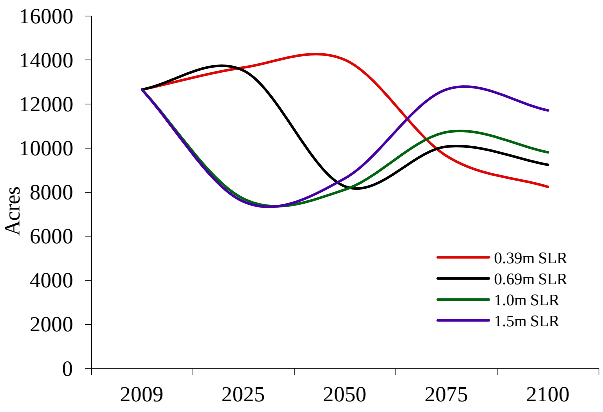

Figure 19-A. Forecasted changes in low tidal habitat using NED elevation data.

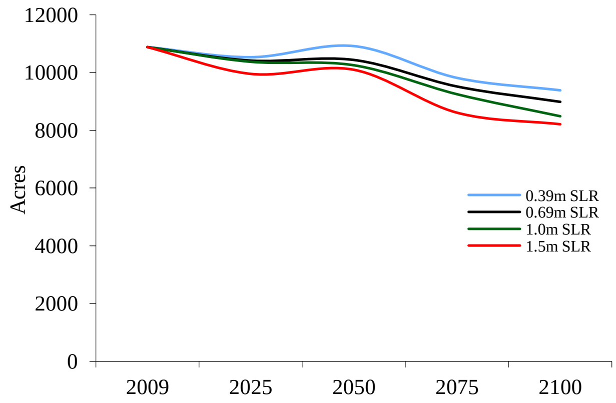

Figure 20-A. Forecasted changes in low tidal habitat from using LIDAR elevation data

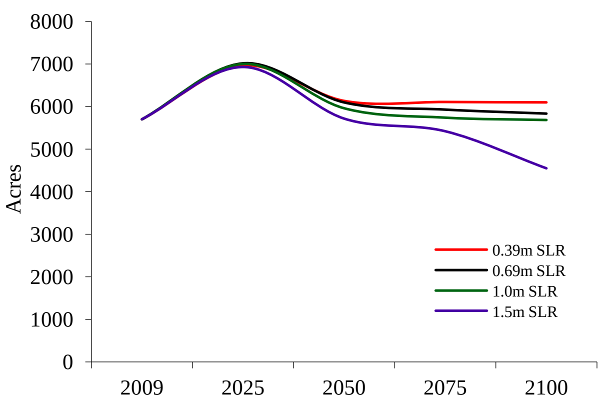

Figure 21-A. Forecasted changes in saltmarsh habitat using LIDAR elevation data.

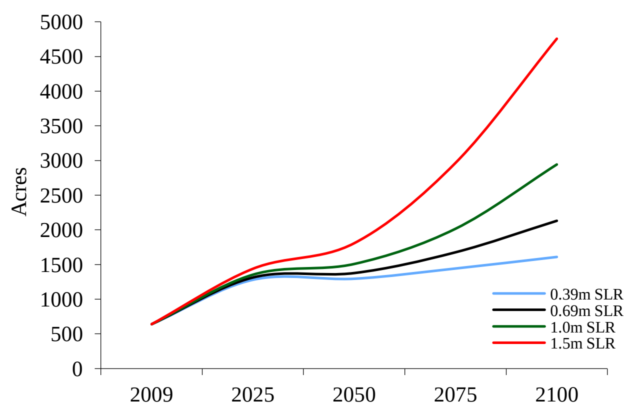

Figure 22-A. Forecasted changes in transitional marsh habitat using LIDAR elevation data.

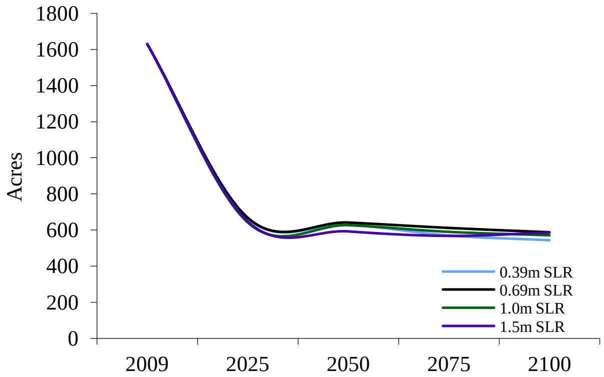

Figure 23-A. Forecasted changes in freshwater tidal habitat using NED elevation data.

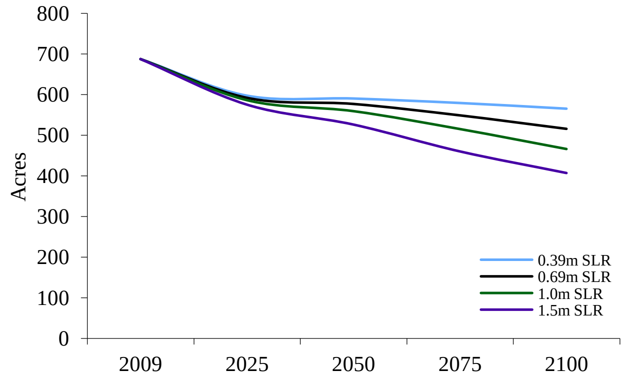

Figure 24-A. Forecasted changes in freshwater tidal habitat using LIDAR elevation data.

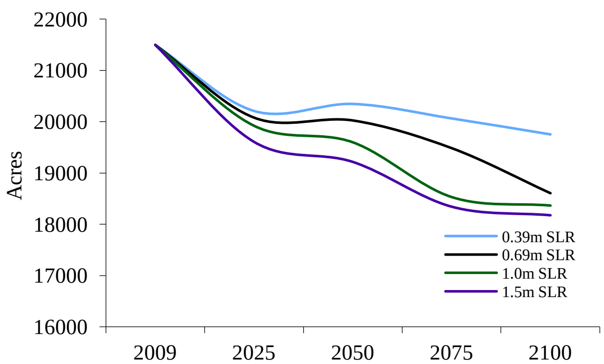

Figure 25-A. Forecasted changes in freshwater habitat using NED elevation data

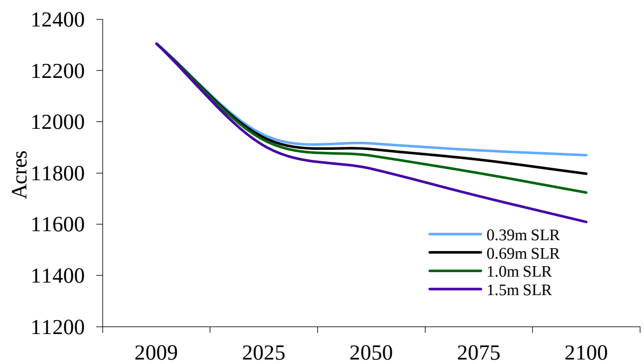

Figure 26-A. Forecasted changes in freshwater habitat using LIDAR elevation data

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LITERATURE CITED

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