

I. INTRODUCTION

This report compiles existing knowledge on known and potential climate change effects on freshwater aquatic and riparian ecosystems within the geographic extent of the North Pacific Landscape Conservation Cooperative (NPLCC). The report also includes a menu of policy and management responses, culled from published science and grey literature, to adapt to climate change in marine and coastal environments. The North Pacific Landscape Conservation Cooperative is one of twenty-one Landscape Conservation Cooperatives (LCCs) planned for the United States, Canada, and Mexico.¹ LCCs are member-directed conservation partnerships among State and Federal agencies, Tribes, nongovernmental organizations, universities, existing partnership efforts, and other conservation entities.² Other key partners of the NPLCC will be the three regional Climate Science Centers (CSCs) within the geographic area of the NPLCC – Alaska, Northwest, and Southwest CSCs.³ The CSCs will deliver basic climate change impact science for their region, prioritizing fundamental science, data and decision-support activities based principally on the needs of the LCCs.⁴ LCCs will link the science with conservation delivery.⁵ Thus, LCCs are management-science partnerships that inform resource management actions and provide needed tools.⁶ More specifically, LCCs generate applied science to inform conservation actions related to climate change, habitat fragmentation, and other landscape-level stressors and resource issues.⁷ For further information, please see <http://www.fws.gov/science/shc/lcc.html> (accessed March 14, 2011).

Description of NPLCC

The NPLCC region comprises approximately 204,000 square miles (530,000 square kilometers, km²) in seven western U.S. states and Canadian provinces (see Figure 1).⁸ The inland extent of the NPLCC is delineated according to the Pacific Flyway, ecoregions, and the crests of several mountain ranges and, from the coast, stretches inland up to 150 miles (~240 km); therefore only the lower extent of many of the larger river watersheds are included within the area. The total amount of coastline is approximately 38,200 miles (~ 61,500 km)⁹ and extends from Kenai Peninsula in southcentral Alaska to Bodega Bay in northern California. Public lands make up approximately 78 percent, or 159,000 square miles (412,000

¹ *US Fish and Wildlife Service (US FWS). *Landscape Conservation Cooperatives: Better Conservation through Partnerships in the Pacific Region*. (2010, p. 1)

² *US FWS. *North Pacific Landscape Conservation Cooperative*. (August 2010, p. 1)

³ US FWS. *North Pacific Landscape Conservation Cooperative (pdf, website)*. (December 2010, p. 2). A total of eight CSCs are being established to support the 21 LCCs. They consist mainly of university-based consortiums.

⁴ *U.S. Department of the Interior. *Interior's plan for a coordinated, science-based response to climate change impacts on our land, water, and wildlife resources (pdf, website)*. (n.d., p. 2)

⁵ *U.S. Department of the Interior. (n.d., p. 5)

⁶ *US FWS. (August 2010, p. 1)

⁷ *US FWS. (August 2010, p. 1)

⁸ US FWS. *North Pacific Landscape Conservation Cooperative High Resolution Map*. (2010). Within the Yukon Territory (YT; 186,272 mi², 482,443 km²), the only land within the NPLCC region is that covered by the Kluane National Park and Preserve (8,487 miles², 21, 980 km²; ~4.6% of total area in YT), located in the southwest corner of the Territory. Given the climate impacts in this area are likely to be more similar to adjacent lands in BC and AK than to the Territory as a whole, this report does not specifically address climate data and research from YT. While information on climate change adaptation planning in Kluane National Park and Preserve was limited, information for the Government of Yukon was available. Please see Chapter #, Section # for further information.

⁹ US FWS. (2010)

km²) of the NPLCC, with 82,000 square miles (212,000 km²) of Federal lands in the U.S. portion of the NPLCC and 77,000 square miles (200,000 km²) of Crown lands in the Canadian portion of the NPLCC.¹⁰

Numerous small to medium-sized rivers and small, high elevation lakes occur throughout the region.¹¹ Several large freshwater and saline lakes are also prominent, as is Puget Sound.¹² To the north, glaciated basins increase and are especially common in Alaska.¹³ Land types include wetlands, glaciers, forests, beaches, and estuaries. A wide variety of fish, wildlife, and other organisms populate this region. For example, forested habitats in the Pacific Coast range support many resident and migrant birds including the marbled murrelet, spotted owl, and Queen Charlotte goshawk, all species of conservation concern.¹⁴ Recently deglaciated habitats in coastal Alaska are important to breeding Kittlitz's murrelets, also a species of concern.¹⁵

Organization of Report

Key findings begin in Chapter II, which describes observed trends and future projections, both globally and within the NPLCC geography, for greenhouse gas concentrations, temperature, and precipitation. Chapter III describes the primary effects of changes in greenhouse gas concentrations, temperature, and precipitation on the region's hydrology. The report then describes how the changes presented in Chapter II and the effects on hydrology presented in Chapter III impact freshwater ecosystems (Chapter IV), species, populations, and biological communities (Chapter V), and specific fish, amphibians, and macroinvertebrates in the NPLCC region (Chapter VI). In Chapter VII, the report provides a menu of policy and management responses to address the impacts of climate change on species and habitats in the freshwater environment described in Chapters IV-VI. These responses are based on general tenets of climate change adaptation for natural systems and are culled from published scientific literature, grey literature, and interviews with experts throughout the NPLCC region. Chapter VIII briefly describes future work in the NPLCC region. Five appendices provide key terms and definitions, an explanation of climate modeling and emissions scenarios, an explanation of long-term climate variability, resources for adaptation principles and responses to climate change, and a list of reviewers and interviewees.

Definitions for Freshwater Aquatic and Riparian Environments

This report covers freshwater ecosystems, their hydrology, and the major physical components of these systems: wetlands, rivers, streams, lakes, ponds, reservoirs, and glaciers.¹⁶ **Freshwater ecosystems** are aquatic systems which contain drinkable water or water of almost no salt content.¹⁷ **Hydrology** is the science encompassing the behavior of water as it occurs in the atmosphere, on the surface of the ground, and underground; the *hydrologic cycle* refers to the existence and movement of water on, in, and above the Earth.¹⁸

¹⁰ US FWS. (2010)

¹¹ *Melack et al. *Effects of climate change on inland waters of the Pacific coastal mountains and western Great Basin of North America*. (1997, p. 972)

¹² *Melack et al. (1997, p. 972)

¹³ *Melack et al. (1997, p. 972)

¹⁴ US FWS. (December 2010, p. 1)

¹⁵ US FWS. (December 2010, p. 1)

¹⁶ U.S. Environmental Protection Agency (EPA). *Aquatic Biodiversity: Freshwater Ecosystems (website)*. (2010)

¹⁷ *U.S. EPA. (2010)

¹⁸ *Brooks et al. *Hydrology and the Management of Watersheds*. (2003)

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water; wetlands may be permanent or intermittent (e.g. seasonal).¹⁹ The U.S. Fish and Wildlife Service (FWS) defines wetlands as lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.²⁰ Major freshwater wetland types in the NPLCC region include non-tidal marshes such as wet meadows and vernal pools, forested and shrub swamps, bogs, and fens.²¹ Wetlands can be found in lowlands or coastal areas, yet they frequently form the headwater areas for streams or lakes.²² The patterns of water depth and the duration, frequency, and seasonality of flooding together constitute a wetland's hydroperiod, which determines its vegetation composition, habitat for aquatic organisms, and other ecosystem characteristics.²³

Streams are defined as the water flowing in a natural channel (as distinct from a canal); *river* is the common term for a large stream.²⁴ The habitats and species that utilize a stream are determined by the stream's shape (i.e., straight, winding, width), the number of branches (zero, one, two or more), the types of rocks and soils that make up the channel and banks, access to and elevation compared to groundwater, and their characteristics over time and space (i.e., continuous, intermittent, seasonal or ephemeral flow; spatial continuity or interruption among stream segments).²⁵

Lakes and reservoirs are deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than thirty percent coverage; (3) total area exceeds twenty acres (eight hectares).²⁶ A lake may be defined more simply as a very slowly flowing or nonflowing (lentic) open body of water in a depression and not in contact with the ocean (the definition includes saline lakes but excludes estuaries and other mainly marine embayments).²⁷ Reservoirs are distinguished from lakes: they are constructed by humans, often within river corridors, and levels are generally controlled by an outlet at a dam. Natural lakes that have been dammed may also function as partial reservoirs.

A **glacier** is a mass of land ice, formed by the further recrystallization of firn (i.e., old snow that has become granular and compacted), flowing continuously from higher to lower elevations.²⁸

¹⁹ *U.S. FWS. 660 FW 2, *Wetlands Classification System (website)*. (1993)

²⁰ Cowardin et al. *Classification of Wetlands and Deepwater Habitats of the United States*, FWS/OBS-79/31. (1979, p. 3)

²¹ U.S. EPA. *Wetlands – Wetland Types (website)*. Available at http://water.epa.gov/type/wetlands/types_index.cfm (accessed 8.22.2011).

²² Brooks et al. (2003, p. 120)

²³ Poff, Brinson and Day. *Aquatic ecosystems and global climate change: potential impacts on inland freshwater and coastal wetland ecosystems in the United States*. (2002, p. 18-19)

²⁴ Brooks et al. (2003); U.S. Geological Survey. *General introduction and hydrologic definitions (website)*. (2008)

²⁵ Brooks et al. (2003); USGS (website).

²⁶ *Dahl. *Status and trends of wetlands in the conterminous United States 1986 to 1997*. (2000, p. 75). Lakes and reservoirs are part of the lacustrine system, as indicated in Table 1 (p. 15) of the cited report.

²⁷ Dodds & Whiles. (2010, p. 143)

²⁸ *American Meteorological Society. *Glossary of Meteorology (website)*. (n.d.)

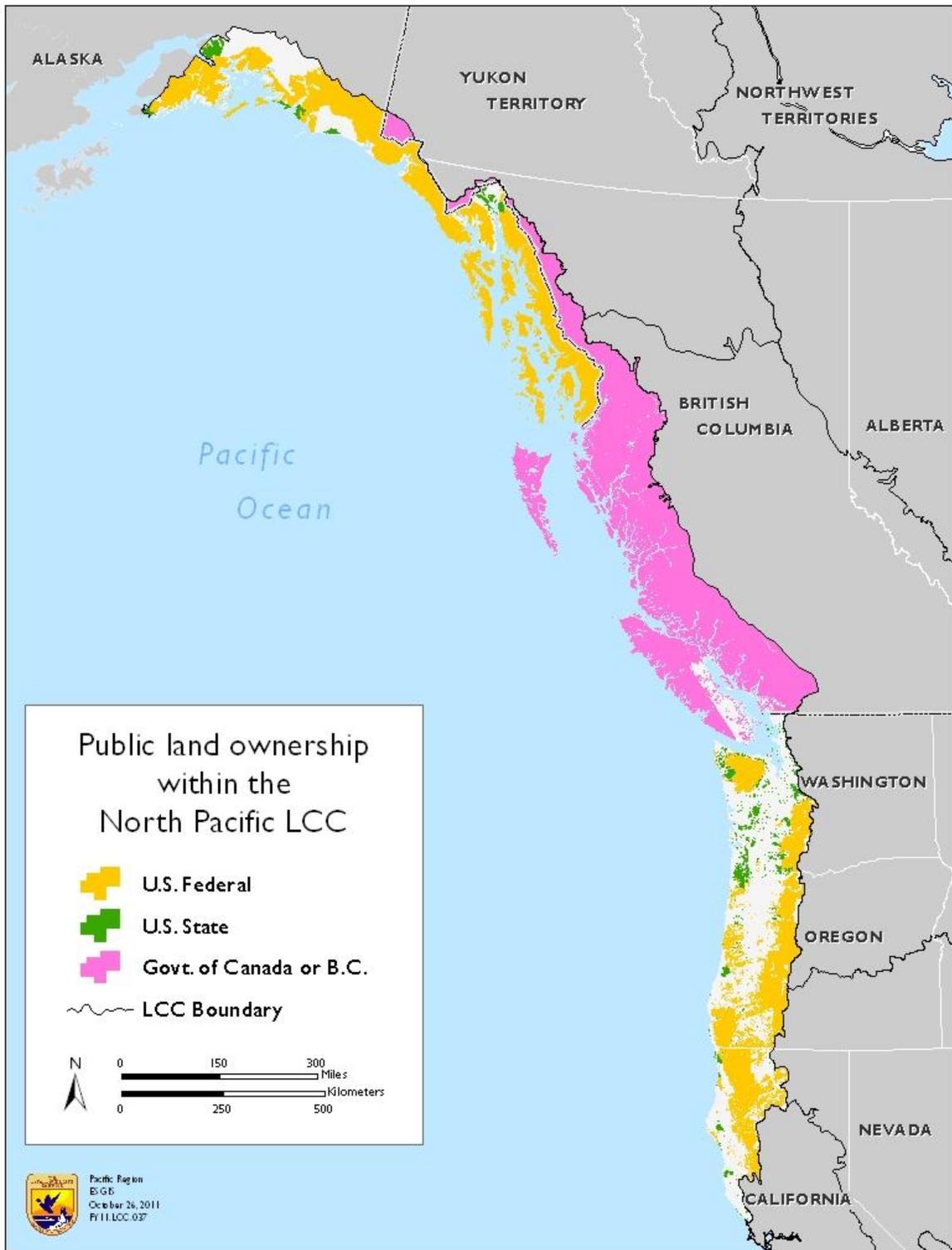


Figure 1. Public land ownership within the North Pacific Landscape Conservation Cooperative (NPLCC). Source: U.S. Fish and Wildlife Service (2011). This is a preliminary land ownership map, including only federal, state, and provincial lands. At a later date, the map will be updated to include Native Alaskan, First Nations, and Tribal lands. Lands owned by other entities (e.g. NGOs, private property) may be included as well.