Advancing Landscape-Scale Conservation

An Assessment of Climate Change-Related Challenges, Needs, and Opportunities for the North Pacific Landscape Conservation Cooperative

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Executive Summary

This report provides an assessment of climate change-related challenges, needs, and opportunities to advance landscape-scale conservation, climate change adaptation, and sustainable resource management in the North Pacific Landscape Conservation Cooperative (NPLCC) region. The NPLCC funded this report to inform NPLCC members, specifically the Science and Traditional Ecological Knowledge (S-TEK) Subcommittee, as they assess priorities and develop their 2013-2016 Strategy for Science and Traditional Ecological Knowledge.[1] The report identifies conservation delivery, applied science, and science and data provision opportunities the NPLCC could consider to support resource managers, conservation practitioners, and researchers in their efforts to conserve and manage ecosystems, habitats, and species in light of climate change effects.[2]

Information for this assessment was collected from 195 natural and cultural resource managers, conservation practitioners, and researchers working at the nexus of climate change and ecosystem response in the NPLCC region. Data was gathered through a survey, thirteen web-based focus groups, and three in-person workshops between September 2011 and June 2012. Participants were asked to identify challenges they faced addressing climate change in their work, approaches they use to overcome those challenges, and suggestions for how the NPLCC could support improved landscape-scale conservation and sustainable resource management in an era of climate change. Data were analyzed using the grounded theory approach to qualitative data analysis, which is an iterative process of data collection and analysis through which participants" input is collected, assessed, and synthesized to generate research results.[3] The University of Washington Climate Impacts Group and Insight Decisions, LLC guided the development of this report and the associated project methodology.

Box 1. Landscape Conservation Cooperatives

Twenty-two Landscape Conservation Cooperatives (LCCs) are planned for North America. As member-directed conservation partnerships among State and Federal agencies, Tribes, nongovernmental organizations, universities, existing partnership efforts, and other conservation entities, LCCs identify and address the landscape-scale conservation needs of their members and stakeholders. LCCs generate applied science to inform conservation actions related to climate change, habitat fragmentation, and other landscape-scale stressors and resource issues, thereby linking science with conservation delivery. By working within and across institutional and geographic boundaries, LCCs provide platforms for communication, relationship building, and stakeholder engagement from which barriers to landscape-scale collaboration and governance can be overcome.

Sources: U.S. FWS (2010a), Jacobsen & Robertson (2012)

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[1] While the primary function of the assessment is to inform the NPLCC and S-TEK, the results are also pertinent for those interested in a better understanding of the challenges, needs, and opportunities germane to project participants.
[2] There are several regional and subregional assessments of physical and ecological climate change impacts in the NPLCC region (e.g., BC MOE 2006, Biodiversity BC 2009, CA NRA 2009, CIG 2009, Nelitz et al. 2007, OCCRI 2010, Pike et al. 2010, Tillmann & Siemann 2011a & 2011b), but far fewer assessments of what resource managers and conservation practitioners will need in order to respond effectively to climate change effects. Available assessments focus on practitioners" needs in marine and coastal ecosystems; none focus on the NPLCC specifically (Finzi Hart et al. 2012, NOAA 2011). This assessment focuses on practitioner needs in the NPLCC region.
[3] See Chapter II. Methodology and Appendix 3. Technical Supplement for additional information.

The geographic focus of the assessment is the NPLCC region, which extends from Kenai Peninsula in southcentral Alaska to Bodega Bay in northwest California, west of the Cascade Mountain Range and Coast Mountains (Figure 1, p. 5). The NPLCC region ranges over 1500 miles (~2400 km) from north to south, up to 150 miles (~240 km) inland, and includes approximately 38,200 miles (~61,500 km) of coastline.[4] The landscape is dominated by forests and some of North America‟s longest rivers, while the seascape is characterized by highly productive coastal waters, estuaries, and rocky shorelines. Strong linkages among the region‟s marine, freshwater, and terrestrial ecosystems are evident in the species that link these ecosystems, such as salmon, and the strong cultures that depend upon healthy, resilient habitats.

As noted by project participants and cited in the scientific literature, climate change is already affecting the NPLCC region‟s ecosystems and wide-ranging changes are projected to continue.[5] These changes include habitat loss and transition, increasing biological stress on salmon and other key species, and the possibility of novel assemblages of habitats and species as species shift their range, phenological relationships change or are disrupted, and interactions with invasive and non-native species are altered.[6] These impacts present a number of challenges and opportunities for resource managers, conservation practitioners, and researchers and highlight the potential role the NPLCC can play in supporting efforts to address climate change impacts on ecosystems, habitats, species, and indigenous resources in the region.

Qualitative analysis of participant input suggests six categories of challenges, four core needs, and seventeen activity areas particular to ecosystems, habitats, species, and indigenous resources. Table 1 (p. xv) lists the core needs and activity areas from the most- to least-frequently cited by project participants.

Challenges

Project participants described a number of specific challenges in response to questions about managing ecosystems, habitats, species, and indigenous resources in light of current and projected climate change effects. Through the analysis of survey responses, web-based focus group input, and in-person workshop results, these challenges were grouped into six themes, summarized below, that emerged as representative categories for the specific challenges described by participants in this assessment:

- **It is difficult to identify, understand, and use climate change science, data, tools, and/or information:** Information on climate change effects is difficult to find, not available at an appropriate scale, or is not available in a format accessible, comprehensible, and useful in project participants‟‟ diverse areas of expertise.
- **Insufficient capacity inhibits addressing climate change:** Despite significant interest in addressing climate change, insufficient human, financial, technical, political, and institutional capacity prevents planning, action, or acquisition of knowledge to adequately address climate change issues.
- **Several non-scientific barriers inhibit efforts to collaborate on and communicate climate change:** Among climate change professionals, international boundaries and institutional silos and culture are the primary impediment to collaboration.[7] Political, cultural, and social barriers most

[4] USFWS (2010b)
[5] See, for example, Tillmann & Siemann (2011a, 2011b)
[6] See, for example, Tillmann & Siemann (2011a, 2011b)
[7] For information on the role of LCCs, in general, in overcoming these barriers, see Jacobson and Robertson (2012).

hinder communication between climate change professionals and policy makers, educators, and the public.

- **There is inadequate coordination, collaboration, and communication among people, projects, institutions, and funding:** With the NPLCC"s extended north-south gradient, many similar projects are taking place across institutional and international boundaries yet it is difficult to coordinate with peers and colleagues working in similar fields and to leverage opportunities to collaborate on projects.[8]
- **It is difficult to incorporate or address uncertainty:** Project participants find it difficult to address uncertainty in climate projections or in the response of ecosystems to current and projected climate change effects. The effectiveness of conservation and management actions in a changing climate and the ability of institutions to respond to climate change are additional sources of uncertainty. Climate-related uncertainties are in some cases novel or are unfamiliar in an area of expertise.
- **Climate-related priorities compete with other priorities and climate change has not been mainstreamed sufficiently into current environmental priorities:** Climate change issues compete with other environmental, economic, or social issues for the time, attention, and funding of people and institutions. In many cases, climate change is still not being considered in planning, regulatory decision-making, and other venues, yet climate change effects will have important implications for the effectiveness of these decisions and the overall health and resilience[9] of ecosystems, habitats, species, and resources.

Core Needs and Opportunities

As a cross-jurisdictional partnership organization, the NPLCC may be well-suited to address many of the landscape-scale conservation, climate change adaptation, and sustainable resource management needs identified by project participants.[10] Based on the analysis of survey responses, web-based focus group input, and in-person workshop results, project participants identified four core needs that, if addressed by the NPLCC, would best advance their efforts to address climate change at the landscape scale. These core needs were identified frequently across the seventeen venues available to project participants, as well as repeatedly within venues; the seventeen venues include a survey, thirteen web-based focus groups, and three in-person workshops. Frequent requests are those occurring in more than half of the seventeen venues. Repeated requests are those made by many participants within venues. The four core needs are:

1. Decision-support systems and tools
2. Collaboration and other capacity-building activities
3. New or different science, data, and information
4. Science communication and outreach

[8] Jacobson & Robertson (2012) discuss LCCs" role in improving coordination, collaboration, and communication.
[9] As Morecroft et al. (2012) note "resilience has a range of meanings and is not used consistently" (p. 547). In this assessment, resilience refers to the definition used by the IPCC: "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change" (Parry et al. 2007, p. 880). In other words, the system can absorb or recover from disturbance without a major phase shift (CCSP 2008).
[10] Jacobson and Robertson (2012) discuss these concepts for LCCs specifically. Berkes (2009), Folke et al. (2005), and others discuss these concepts with regard to the evolution of co-management, bridging organizations, and adaptive governance of social-ecological systems generally.

1. Decision-support systems and tools (DSS and DST)

DSS and DST were requested in all seventeen venues. DSS and DST aid decision making by gathering decision-relevant documents, data, and other resources in a single platform and enabling managers and decision makers to use those resources to inform decisions.[11] Project participants emphasized visual displays of information such as maps and 3-dimensional animations rather than written products because they are a powerful and effective method for conveying information and galvanizing action. They also stated improvements in existing maps and geospatial tools would support conservation and evaluation under changing climatic conditions. Consistent with recent assessments of strategies and methods for climate-related decision support and decision makers" adaptation needs, project participants also noted DSS and DST are most effective when designed with a particular audience, goal, and ecosystem in mind.[12] Training increases the likelihood that tools will be useful *and* used, and is therefore a key component of development and implementation.[13] Project participants also suggested DSS and DST should always include detailed metadata and should reflect a dynamic, not static, environment. With these principles in mind, project participants suggested the NPLCC would be well-suited to support DSS and DST because these systems and tools are critical inputs to on-the-ground resource management and conservation decisions. Specific examples of requested DSS and DSTs include:

- Vulnerability assessments to aid early prioritization efforts, help participants defend their work, and help determine the needed intensity and location of conservation activities and adaptation actions (Chapter III.1). Examples of requested vulnerability assessments include wetland vulnerability to sea-level rise and associated stressors (Chapter VI.1), key species in southeast Alaska island ecosystems (Chapter VII.2), and Pacific salmon (Chapter VIII.1).
- Maps and characterizations of the marine nearshore and estuarine environment to identify the current and potential future distribution of intertidal habitats and species (Chapter VI.1).
- A DST to assess short- and long-term management options and tradeoffs for focal species and indicators (Chapter VIII.3). The focal indicators identified emphasize functional, obligate[14] biophysical and ecological relationships that are key determinants of the overall health and resilience of the ecosystem. Suggested focal species include small endemic mammals for the Alexander Archipelago in southeast Alaska and salamanders for northwest California.

2. Collaboration and other capacity-building activities

Collaboration and other capacity-building activities were requested in 15 of 17 venues and include collaboration among people, projects, institutions, and/or funding sources.[15] Project participants emphasized the need for projects and plans that meet multiple objectives of multiple partners in locations vulnerable to climate change effects. They also emphasized the need to build long-term landscape-level

[11] NRC (2009)
[12] See also, NRC (2009) and Finzi Hart et al. (2012)
[13] See also, NRC (2009) and NOAA (2011)
[14] Obligate species refer to “a plant or animal that occurs only in a narrowly defined habitat such as a tree cavity, rock cave, or wet meadow” (StreamNet 2013). A related term, obligate symbiosis, refers to species relationships in which “the host or symbiont depends entirely upon the other for some type of capability or function which they do not possess” (Seckbach 2002, p. 760).
[15] The venues include all but two web-based focus groups: Puget Sound and Georgia Basin Freshwater and Lowlands, Prairies, and Other Non-forested Systems.

resilience to climate change effects and related stressors in a way that enhances current resilience and responds to short-term needs and constraints. Such an approach would help ensure the viability and success of projects and plans over time. Project participants stated the NPLCC would be uniquely positioned to help them overcome barriers to collaboration and to facilitate other capacity-building activities because the region crosses international, state, and institutional boundaries and encompasses diverse ecosystems and climatic zones that nonetheless share similar climate change-related threats (e.g. increased air and water temperatures, altered hydrologic regimes, ocean acidification, sea-level change, coastal erosion and flooding).[16] Frequently requested needs and activities include:

- Convene researchers and managers from across ecosystems to respond to climate change at the landscape scale. Tackle cross-ecosystem integration and associated challenges (Chapter III.2).
- Provide "actionable-level" information and tangible examples of progress or success with climate change adaptation (Chapter III.2).
- Assess the pros and cons of existing data and information portals, and develop a data portal or "climate clearinghouse" with a brief description of people, their projects, and how to contact them (Chapter III.2).
- Leverage and build upon existing efforts to coordinate fog research (Chapter VII.4) and facilitate collaboration and communication between Tribes and resource agencies (Chapter IV.1). These are two of several examples of collaboration and capacity-building activities specific to ecosystems or resources requested by project participants (see Chapters IV-IX for others).

3. New or different science, data, or information

In 15 of 17 venues, project participants identified a number of fundamental data gaps and information needs throughout the NPLCC region.[17] Some data gaps and information needs are shared throughout the NPLCC region, while others are particular to a specific location or ecosystem. While project participants requested assistance from the NPLCC and other entities to fill these gaps and address information needs, they also emphasized a valuable role of the NPLCC would be to help ensure compatibility with existing sources of information and an organized approach to store and access the information.[18] Examples of requested science, data, and information include:

- Fundamental or baseline data such as hydrologic data in Alaska and British Columbia (Chapter V.1) or measurement of coastal sediment accretion, flux, and transport (Chapter VI.1).
- Models and downscaling efforts such as regional and local models of ocean conditions (Chapter VI.2), models linking hydrologic changes to species and habitat responses (Chapter V.1), and models of invasive species and disease relationships (Chapter IX.1).
- Climate and socioeconomic scenarios that capture a range of possible futures, developed in collaboration with decision makers and stakeholders (Chapter III.3).
- Cost estimates and cost-benefit analyses, for example of coastal flooding impacts (Chapter VI.4).

[16] Jacobsen & Robertson (2012) state LCCs "have great potential to facilitate conservation of rapidly changing social-ecological systems by providing structure and incentives for collaboration and shared learning" (p. 333).
[17] The venues include all but two web-based focus groups: Alaska and British Columbia Coast Freshwater and Interior Mountain Ecosystems.
[18] The latter roles are also identified as thematic needs in NOAA"s (2011) societal needs assessment for coastal sea-level change.

4. Science communication and outreach

Science communication and outreach was suggested in 11 of 17 venues.[19] Project participants indicated the NPLCC‟s on-the-ground focus may make it well-suited to generating or supporting science communication and outreach in the NPLCC region.[20] Three audiences were identified for targeted communication and outreach: resource managers, conservation practitioners, and researchers; the public and educators; and, decision makers. Project participants frequently stated it is important to provide "good, consistent language" for communicating with policymakers and the public and to translate scientific information into a language understood by the target audience; these principles are also identified in similar needs assessments and studies.[21] Examples of requested communication and outreach needs and activities include:

- Communicate the impacts of sea-level rise on the nearshore environment to support proactive responses (Chapter VI.4).
- Use visualization tools to communicate climate change effects and examine potentially vulnerable areas (Chapter VI.4 and VI.3, respectively). The former was cited as a successful approach.
- Connect ecological impacts with social and economic impacts, especially when communicating with decision makers and the public (Chapter III.4).

Activity Areas for Ecosystems, Habitats, Species, & Indigenous Resources

In addition to the four core needs just described, project participants suggested a range of activities that could address climate change effects and advance landscape-scale conservation, climate change adaptation, and sustainable resource management for the NPLCC‟s indigenous resources, ecosystems, habitats, and species. Through the analysis of survey responses, web-based focus group input, and in-person workshop results using the grounded theory approach, these activities were categorized and synthesized into seventeen activity areas. An *activity area* is a discrete grouping of activities requested by project participants that are similar in terms of the climate change impacts addressed and the challenges or constraints faced by project participants in trying to engage in the activities. Each activity area was evaluated to determine how many of the seventeen venues the activity area was cited in (its frequency) and the number of times an activity area was discussed within venues (its repetition) (Table 1 on p. xv, Figure 2 on p. 17).[22] Within an activity area, individual activities were evaluated by project participants to ascertain the decision(s) the activities would inform (i.e., decision relevance), the needed spatial and

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[19] The venues are the survey, all five web-based focus groups for marine and coastal ecosystems, three of the five web-based focus groups for freshwater ecosystems (Alaska and British Columbia Freshwater, Pacific Coast and Nass Ranges Freshwater, Puget Sound and Georgia Basin Freshwater), and the Juneau and Arcata workshops.
[20] See also, Jacobsen and Robertson (2012). They suggest LCCs are bridging entities within a broader co-governance framework and may therefore provide "platforms for communication, relationship building and stakeholder engagement" (p. 333). For example, through the North Atlantic LCC‟s communication and information-sharing platform, "disparate stakeholder groups are identifying shared conservation priorities and designing coordinated conservation actions to address those priorities" (p. 337).
[21] NRC (2009), NOAA (2011), Finzi Hart (2012)
[22] Recall that frequent requests are those occurring in more than half of the seventeen venues available to project participants (the seventeen venues include a survey, 13 web-based focus groups, and three in-person workshops). Repeated requests are those made by many participants in many venues.

temporal scale to target, the timeline and sense of urgency for engaging in the activity, and partners and ongoing efforts available to assist with the activity.

Given the variety of requested activities and diverse expertise available in the region, some of the activity areas will be better addressed by NPLCC partners, including Climate Science Centers, individual agencies or ministries, and other entities. Coordination with partners will be important to identify the appropriate entity to address a particular activity area and to facilitate efforts to respond to the items that are not well-suited to the role of the NPLCC.

All the activities listed in these activity areas are examples of the four core needs previously described. Activity areas may reflect a single ecosystem type – marine, freshwater, or terrestrial – or be cross-ecosystem – representing some combination of marine, freshwater, and terrestrial ecosystems, species that utilize one or more ecosystems, or indigenous resources found in one or more ecosystems. Thus, the strong linkages among the NPLCC region‟s marine, freshwater, and terrestrial ecosystems and the cultures that depend upon them are reflected in the activity areas, especially those requested most frequently across venues and repeatedly within venues.

Activity areas for indigenous natural and cultural resources

Project participants repeatedly discussed the importance of addressing climate change effects on indigenous natural and cultural resources. It was a common cross-cutting theme in many venues, particularly the in-person workshops where indigenous natural and cultural resources were discussed in the context of challenges and needs for ecosystems, habitats, and species. Two activity areas were identified:

1. **Support the efforts of Tribes, Native Alaskans, and First Nations to identify and address climate-related priorities related to decision-support and capacity-building (9 of 17 venues):**[23] Project participants noted capacity to address and adapt to climate change effects varies widely among the many Tribes, First Nations, and Native Alaskan communities in the NPLCC region. Some communities are innovating approaches to climate change adaptation, while others are just beginning to address climate change. In order to build capacity in tribal communities, a key issue to address is deciding if and how to share and integrate traditional ecological knowledge and western science in all endeavors, including climate change work. Many project participants stated the sharing of traditional knowledge, which is culturally sensitive and proprietary, should be led by indigenous communities.[24] Project participants also noted that existing projects incorporating traditional ecological knowledge and western science provide a foundation from which to broaden and deepen new efforts to integrate these two knowledge systems. Suggested collaboration and communication activities include coordinating local testimonies of climate change impacts, working with First Nations to advance federal climate change efforts, and facilitating collaboration between Tribes and resource agencies, which can strengthen formal consultation processes and the Government-to-Government relationship

[23] The venues are the survey, five web-based focus groups (Southcentral and Southeast Alaska Marine, California Current Marine #1 and #2, Pacific Coast and Nass Ranges Freshwater, Columbia River Basin Freshwater), and all three workshops.
[24] See also, Lynn (2012), Lynn and Zakai (2012)

between the U.S. government and federally-recognized tribes by building strong relationships and respect between sovereign governments.[25]

2. **Address climate change effects on the Indigenous Way of Life (6 of 17 venues):[26]** Acknowledging that environmental health and resilience is crucial to maintain the Indigenous Way of Life, project participants emphasized the urgency of identifying and assessing the most vulnerable cultural and natural resources in light of current and projected climate change effects.[27] Project participants suggested an effective strategy may be for science organizations to produce easily accessible data and research such as data on the health and vulnerability of fish, shellfish, and other resources.[28] Project participants further suggested the data and research should assist collaboration at the highest levels within agencies and organizations and would serve as a source of climate-related information for tribes, which would enable indigenous communities to apply research from western science as well as their traditional ecological knowledge in addressing climate change.[29]

Activity areas for freshwater ecosystems and habitats

In 13 of 17 venues, project participants discussed increasing the resilience of the hydrologic regime to climate change and related stressors.[30] The most frequent and repeated requests were for an improved sensor and monitoring network, and the vulnerability assessments, prioritization tools, and other capacity-building and decision-support activities that provide actionable-level information and enable action on-the-ground. These requests were made in discussions focusing on marine, freshwater, and terrestrial ecosystems; they are cross-ecosystem requests for the region. In Alaska and British Columbia, there was also frequent discussion of assessing the effects of climate change and related stressors on hydropower and hydropower infrastructure, particularly in light of a lack of consideration of climate change in current permitting processes.[31]

Activity areas for coastal ecosystems and habitats

Project participants often requested baseline data and modeling results to use as inputs for decision-support tools related to coastal ecosystem and habitats. Participants frequently requested this information

[25] See also, Lynn (2012), Lynn and Zakai (2012), and Box 5 (p. 61) in this report.
[26] The venues are Southcentral and Southeast Alaska Marine, Pacific Coast and Nass Ranges Freshwater, Columbia River Basin Freshwater, Coastal Temperate Rainforest Ecosystem, and the Juneau and Arcata workshops.
[27] This activity was identified by participants from the survey, Southcentral and Southeast Alaska Marine, Pacific Coast and Nass Ranges Freshwater, Columbia River Basin Freshwater, Coastal Temperate Rainforest Ecosystem, and the Juneau and Arcata workshops.
[28] This suggestion was made by participants from the Southcentral and Southeast Alaska Marine web-based focus group and the Juneau and Arcata workshops.
[29] This suggestion was made by participants from the Southcentral and Southeast Alaska Marine web-based focus group and the Juneau and Arcata workshops.
[30] The activity area was identified in the survey, nine web-based focus groups (Southcentral and Southeast Alaska Marine, California Current Marine #1 and #2, Alaska and British Columbia Coast Freshwater, Pacific Coast and Nass Ranges Freshwater, Puget Sound and Georgia Basin Freshwater, WA/OR/n. CA Coastal Ranges and Drainages Freshwater, Coastal Temperate Rainforest Ecosystem, Lowlands, Prairies, and Other Non-forested Systems), and all three workshops.
[31] This activity was identified by web-based focus group participants from the Southcentral and Southeast Alaska Marine, Alaska and British Columbia Coast Freshwater, Pacific Coast and Nass Ranges Freshwater, Coastal Temperate Rainforest Ecosystem web-based focus groups, as well as participants in the Juneau workshop.

to support improved communication and collaboration, and to inform specific management decisions such as the identification of priority conservation and restoration areas. The four activity areas related to coastal ecosystems and habitats are:

1. **Track climate change effects and compare management options in the marine nearshore and estuarine environment (11 of 17 venues):** Project participants emphasized acquisition and organization of fundamental and baseline data in tidal wetlands and estuaries, specifically characterization of the sediment regime, tidal elevation, isostatic rebound,[32] water quality, and vegetation composition.[33] These data feed into the maps, visualization models, and decision-support tools and resources that enable participants to take action to address climate change effects in the marine nearshore and estuarine environment. Given the number and variety of available management options and decision-support tools for the marine nearshore and estuarine environment, project participants repeatedly requested assistance comparing management options, selecting appropriate tools, and identifying when, where, and under what circumstances to use tools in these systems.[34] Addressing these data, information, and capacity gaps would help identify areas of resilience and vulnerability and inform decisions about where and when to conserve, restore, acquire, or enhance areas in the marine nearshore and estuarine environment.
2. **Address potential changes in phenology and food webs due to acidified and low-oxygen ocean conditions (7 of 17 venues):** Project participants requested an improved understanding of the biological and ecological effects of acidified and low-oxygen ocean conditions on phenology and food webs. To better understand potential future effects and inform management decisions, coordination of existing research efforts, modeling ocean conditions with an emphasis on the regional and local scale, and increased science communication and outreach with resource managers and the public were also suggested.[35]
3. **Characterize eelgrass and kelp habitats and identify priority areas (6 of 17 venues):** Project participants requested information on the current distribution and ecology of eelgrass habitats to inform projections of future distribution, assessments of mitigation potential, and economic valuation. A better understanding of the economic and ecological value of these habitats would aid communication with decision makers, acquisition of funding, and efforts to identify priority areas for conservation and restoration.[36] No specific suggestions for kelp habitats were identified.

[32] Isostatic rebound refers to the "vertical movement of the land and sea floor following the reduction of the load of an ice mass" (Baede 2007, p. 950). As glaciers recede, their weight is removed from the land or sea floor surface, causing the surface to "rebound" upward.
[33] These activities were identified by project participants from all five marine ecosystem web-based focus groups, the Puget Sound and Georgia Basin Freshwater and Coastal Temperate Rainforest Ecosystem web-based focus groups, all three workshops, and several survey respondents.
[34] Assistance was requested by project participants from the Puget Sound and Georgia Basin Marine and both California Current Marine web-based focus groups, the Portland and Arcata workshops, and one survey respondent.
[35] These research, research coordination, modeling, and science communication and outreach requests were made by project participants from all three workshops, the Puget Sound and Georgia Basin Marine and both California Current Marine web-based focus groups, and survey respondents. They are also consistent with suggestions found in the Draft Strategic Plan for Federal Ocean Acidification Research and Monitoring (Interagency Working Group on Ocean Acidification 2012) and the National Research Council Report on Ocean Acidification (Levison 2012).
[36] Requests related to eelgrass were made most frequently by web-based focus group participants from British Columbia (specifically, in the British Columbia Coast Marine, Puget Sound and Georgia Basin Marine, and both California Current Marine web-based focus groups) and were also discussed in the Portland workshop.

4. **Inform cost estimates and vulnerability assessments related to altered coastal flooding regimes in Puget Sound and the California Current Region (4 of 17 venues):** To inform cost estimates and enable a more concerted focus on the ecological costs of flooding, development or refinement of models that reflect the Pacific Northwest"s event-driven sediment regimes, seasonal flooding, and other aspects of the hydrologic regime were suggested. Model results and cost estimates can be used in vulnerability assessments and displayed on maps or other visualization tools to improve communication about climate change effects in the nearshore environment.[37]

Activity areas for terrestrial ecosystems and habitats

Project participants frequently requested a landscape-scale approach to addressing climate change effects in terrestrial ecosystems across the NPLCC region. In specific areas of the NPLCC, a variety of research, research coordination, and communication and collaboration activities were requested. The five activity areas related to terrestrial ecosystems and habitats are:

1. **Address climate change effects on large landscapes, especially whole-scale changes in vegetation composition (7 of 17 venues):** Project participants from throughout the NPLCC region requested an increased focus on documenting and addressing whole-scale landscape change in response to current and projected effects of climate change. In terrestrial ecosystems, suggested activities include conducting research and developing scenarios of landscape-level changes in vegetation composition, as well as assessing and monitoring the responses of wildlife habitat and nutrients to climate change effects.[38] In Alaska and British Columbia, assessing the vulnerability of cedar (especially yellow-cedar) to climate change effects was also suggested.[39]
2. **Identify, protect, and maintain the integrity of connectivity and refugia networks in light of climate change effects (7 of 17 venues):** The NPLCC"s extended north-south gradient is both an "invasive species corridor" for dispersal of invasive species into new areas and a pathway for natural species dispersal and migration on daily, seasonal, annual, or other timescales. In either case, project participants indicated the NPLCC geography is uniquely suited to study landscape-scale north-south migrations from the paleorecord into the future and to assess possible changes to the network of habitat and biodiversity conservation corridors[40] (including corridors for dispersal, migration, and commuting) and refugia to enhance climate-resilience in the region (see

[37] These suggestions were made by project participants in the Puget Sound and Georgia Basin Freshwater and California Current Marine #1 web-based focus groups, the Portland workshop, and several survey respondents.
[38] These activities were suggested by participants from the survey, four web-based focus groups (Alaska and British Columbia Coast Freshwater, Puget Sound and Georgia Basin Freshwater, Coastal Temperate Rainforest Ecosystem, Lowlands, Prairies, and Other Non-forested Systems), and especially, the Juneau workshop.
[39] This request was made by project participants from the Juneau workshop, with general support from participants in the California Current Marine #2 web-based focus group.
[40] As noted by Hess and Fischer (2001), the term "corridor" defies simple definition, and the roles corridors play derive from the six ecological functions of habitat, conduit, filter, barrier, source, and sink. In this assessment, project participants referred to corridors chiefly in two ways: (1) **habitat corridors,** defined as "components of the landscape that facilitate the movement of organisms and processes between areas of intact habitat" (Meiklejohn et al. 2009, p. 1-2). Examples include *migration corridors* used for annual migratory movements between source areas, *dispersal corridors* for one-way movements of individuals or populations from one resource area to another, and *commuting corridors* that refer to daily movements within a species" home range to support breeding, resting, foraging, and other activities (Meiklejohn et al. 2009); (2) **biodiversity conservation corridors**, defined as "a biologically and strategically defined sub-regional space, selected as a unit for large-scale conservation planning and implementation purposes" (Sanderson et al. 2003, p. 10-11).

next section for information on invasive species).[41] The NPLCC is also home to naturally fragmented and isolated refugia systems such as Alaska‟s Alexander Archipelago, British Columbia‟s Haida Gwaii, and Washington‟s Olympic Peninsula. To maintain the integrity of these systems, project participants suggested research to characterize biodiversity and ecological and evolutionary dynamics as well as species vulnerability assessments to identify vulnerability hotspots that could be used to guide adaptation decisions.[42]

3. **Study the interaction of fire with other disturbance regimes given current and potential future climate change effects (5 of 17 venues):** Project participants acknowledged that projections for warmer climates and possibly drier climates, particularly in the summer, raise concerns about increased disturbance from fire. As a result, the major recommendation from participants is to acquire an integrated understanding of how fire will interact with other disturbance regimes given current and projected climate change effects, especially in the southern NPLCC region and southcentral Alaska. The emphasis is on understanding future disturbance regimes in order to determine how to respond to stressors and conditions that may be similar or different from the status quo.[43] Participants working in California requested specific attention to addressing fire as a source of disturbance in forested ecosystems.[44]
4. **Conduct more and better coordinated assessments of climate change effects on fog patterns and forest hydrology in northwest California (2 of 17 venues):** A key issue for those currently working in northwest California is to understand potential changes to fog and fog-associated hydrologic regimes and the effects they may have on coastal redwood forest health[45] and resilience. While there is an active research community in northwest California, project participants stated much of the research is in its early stages and should be better coordinated and communicated with the broader stakeholder community.[46]
5. **Support to advance efforts to address climate change in the Willamette Valley, Oregon (2 of 17 venues):** Project participants requested guidance and scenarios to compare and select management options associated with land acquisition and protection, as well as assistance to understand the implications of conflicting scientific results. The spatial focus is the Willamette Valley National Wildlife Refuge Complex and nearby areas. Project participants also requested

[41] These research topics were suggested by project participants from the survey, Puget Sound and Georgia Basin Marine, WA/OR/n. CA Coast Ranges and Drainages Freshwater, Coastal Temperate Rainforest Ecosystem, and Interior Mountain Ecosystem web-based focus groups, and Juneau and Arcata workshops.
[42] This suggestion was made by project participants from the Coastal Temperate Rainforest Ecosystem web-based focus group and Juneau workshop.
[43] These research topics were identified by participants from the survey, Coastal Temperate Rainforest Ecosystem web-based focus group, and the Arcata and Juneau workshops.
[44] This topic was discussed by project participants from the Interior Mountain Ecosystem web-based focus group and Arcata workshop.
[45] In this assessment, "forest health" refers to the definition provided by the U.S. Forest Service (2012): "a measure of the robustness of forest ecosystems. Aspects of forest health include biological diversity; soil, air, and water productivity; natural disturbances; and the capacity of the forest to provide a sustaining flow of goods and services for people."
[46] These requests for research, collaboration, and communication were made by project participants in the Coastal Temperate Rainforest Ecosystem web-based focus group and Arcata workshop.

increased attention to cross-boundary collaboration, both within and across institutions, and science-related outreach that uses good, consistent language to communicate with the public.[47]

Activity areas for species, pathogens, and diseases

In their discussions of opportunities to address climate change effects on species, pathogens, and diseases, project participants focused on fish, specifically Pacific salmon and forage fishes, and terrestrial species such as amphibians and small mammals. They also supported the identification of dispersal corridors likely to be used in response to climate change effects. The five activity areas related to species, pathogens, and diseases are:

1. **Assess the vulnerability of Pacific salmon, other anadromous fish, and their habitats to climate change effects (10 of 17 venues):** While more research is needed, projected increases in ocean temperatures and possible increases in ocean productivity may result in increased abundance in Pacific salmon stocks in the northern NPLCC region and decreased abundance in southern salmon stocks as thermal and flow limits are reached throughout the lifecycle.[48] As a result, Pacific salmon populations in Alaska may be less vulnerable than populations in the southern NPLCC region, with the exception of small populations isolated by geography, temperature, or other barriers, which may be more vulnerable. Project participants suggested studying climate change effects on the Pacific salmon lifecycle and mapping current and projected salmon habitats to assess habitat viability and inform management decisions. In the southern portion of the NPLCC region, a vulnerability assessment of hatchery and wild fish was requested.[49] Other anadromous fish such as coastal cutthroat trout, eulachon, and lamprey were also identified as vulnerable to climate change effects and important to address, but project participants did not provide specific suggestions for these fishes.
2. **Support efforts to identify the dispersal corridors invasive species, pests, pathogens, and diseases are likely to use in response to changes in climate (9 of 17 venues):** Acknowledging the NPLCC region has long been a landscape-scale north-south migration and dispersal corridor for wanted and unwanted species movements, project participants suggested facilitating a NPLCC-wide research partnership, conducting assessments of habitat and resource vulnerabilities, and generating models of adaptive management outcomes.[50] These items build capacity to respond to novel introductions, changes in biological community composition, and resulting effects on culturally and economically important resources.

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[47] These requests were made by project participants in the Lowlands, Prairies, and Other Non-forested Systems web-based focus group and Arcata workshop.
[48] Beamish et al. (2009), Mueter et al. (2002), Okey et al. (2012)
[49] These suggestions were provided by project participants from the survey, six web-based focus groups (Puget Sound and Georgia Basin Marine, California Current #1 Marine, Alaska and British Columbia Coast Freshwater, Pacific Coast and Nass Ranges Freshwater, Puget Sound and Georgia Basin Freshwater, and Columbia River Basin Freshwater), and all three workshops.
[50] These suggestions were provided by project participants from the survey, six web-based focus groups (Southcentral and Southeast Alaska Marine, Puget Sound and Georgia Basin Marine, California Current #1 Marine, Pacific Coast and Nass Ranges Freshwater, Lowlands, Prairies, and Other Non-forested Systems, and Interior Mountain Ecosystems), and the Portland and Juneau workshops.

3. **Generate research and models for forage fishes[51] (6 of 17 venues):** Given the ecological and economic importance of forage fishes[52] and their vulnerability to climate change and other stressors,[53] project participants identified research and modeling of habitat loss, food web impacts, and invasive species interactions as key research and information gaps to address.[54] Results could inform development or modification of management activities such as beach restoration and eelgrass conservation.
4. **Identify focal indicators to track climate change and assess management options (5 of 17 venues):** Project participants from throughout the NPLCC region, particularly those working in terrestrial ecosystems (e.g., see Chapter VIII.3), suggested identifying climate-resilient focal species and habitat indicators (e.g., small endemic mammals, salamanders), conducting habitat assessments, and developing habitat criteria models.[55] They also emphasized the importance of assessing management options and the tradeoffs involved in choosing to manage a particular species or habitat in lieu of another species or habitat over time.[56] Specifically, project participants suggested attention to management options and tradeoffs pertaining to threatened and endangered species and state or U.S. Forest Service species of concern.
5. **Develop vulnerability maps and models to address climate change effects on other key fish species (2 of 17 venues):** Project participants requested vulnerability maps and downscaled models of hydrology, air and stream temperature, and fish habitat change in order to inform the prioritization of restoration and adaptation strategies, as well as management activities related to the Endangered Species Act.[57] Participants also noted these items are relevant for anadromous and forage fishes, as well as other fishes that may emerge as key species in the NPLCC region.

Discussion

Assessments of the climate change adaptation needs of conservation, climate change, and resource management professionals are increasing in number and availability. However, a nuanced understanding of these practitioner needs still lags behind similar knowledge of physical and ecological climate change impacts.

While this assessment identified two technical challenges to meeting practitioner needs (difficulty addressing uncertainty and difficulty identifying, understanding, and using climate change science, data, tools, and/or information), the remaining four challenges identified all address non-technical obstacles to incorporating climate change. These include social, cultural, institutional, and geographic barriers to collaboration and communication, and the resulting lack of capacity, coordination, and communication.

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[51] Forage fishes found in the NPLCC region include sardines, anchovy, Pacific herring, surf smelt, longfin smelt, Pacific sand lance, capelin, eulachon, Atka mackerel, and juvenile walleye Pollock (Penttila 2007, NOAA 2012a).
[52] Lellis-Dibble et al. (2008), Penttila (2007)
[53] Beamish et al. (2009), Krueger et al. (2010), Penttila (2007)
[54] These suggestions were made by project participants from the survey, Southcentral and Southeast Alaska Marine, British Columbia Coast Marine, Puget Sound and Georgia Basin Marine, and California Current #2 Marine web-based focus groups, and the Portland workshop.
[55] These suggestions were made by project participants from the Alaska and British Columbia Coast Freshwater web-based focus group, as well as the Juneau and Arcata workshops.
[56] These topics were discussed by project participants from the survey, Interior Mountain Ecosystems web-based focus group, and Juneau and Arcata workshops.
[57] These requests were made by project participants from the Puget Sound and Georgia Basin Marine web-based focus group and the Portland workshop.

They also include the sense that climate change is not mainstreamed sufficiently into conservation and resource management practice and competes with other issues for the time, attention, and funding of decision makers. This suggests non-technical obstacles to addressing climate change are key impediments to the practitioner‟s ability to address climate change in their daily work and long-range planning, a finding that is often overlooked in standard assessments of the physical and ecological effects of climate change.

The majority of needs and opportunities identified in this assessment respond directly to the non-technical challenges described by project participants. They also emphasize cross-ecosystem approaches to conservation delivery and applied science. Additional key findings from this assessment include:

- Decision-support systems and tools are the dominant need in the NPLCC region. Decision-support systems and tools include ecosystem-specific systems and tools such as current and future distribution maps for a particular habitat, location-specific vulnerability assessments, and computer- or web-based tools for a particular region, habitat, or climate change impact.
- Collaboration, other capacity-building activities, and the generation of new or different science, data, and information are also key needs. Capacity-building activities include guidance, case studies of progress or success in climate change adaptation, development of synthesis products, and facilitating collaboration among people, projects, institutions, and funding sources.
- While a better understanding of current and projected climate change effects on ecosystems, habitats, species, and indigenous resources in the NPLCC region is important, it is also critically important to generate the science, data, and information needed to develop and use decision-support systems and tools, and to build capacity to address climate change effects.
- Among the seventeen activity areas, cross-ecosystem activity areas were cited most frequently across venues and repeatedly within venues (recall that the venues are the survey, web-based focus groups, and in-person workshops).
- Increasing the resilience of the hydrologic network to climate change effects and related stressors is the dominant activity area for ecosystems, habitats, species, and indigenous resources. This is a cross-ecosystem activity area.
- Other key activity areas for ecosystems, habitats, species, and indigenous resources are: (1) assessing the vulnerability and resilience of marine nearshore systems, the estuarine environment, and Pacific salmon; (2) supporting efforts to identify and address climate priorities related to indigenous natural and cultural resources and, (3) a focus on the NPLCC as a migration and dispersal corridor for wanted and unwanted species movements, especially along the north-south gradient. These are cross-ecosystem activity areas.
- Promoting effective science communication and outreach will require targeted messaging and a user-to-consumer approach. This is also considered a key need in the NPLCC region.
- Visualization emerged as a common and dominant theme across the core needs and activity areas. Whether visualizing impacts, developing models, scenarios and other decision-support tools, generating synthesis products, or utilizing web-based resources, information is preferred in a visual and interactive format.

Table 1. Participant-Identified Core Needs and Activity Areas Listed from Most to Least Frequently Cited

**There were three web-based focus groups for terrestrial ecosystems, compared to five web-based focus groups each for marine/coastal and freshwater ecosystems. To account for the difference, a weighting factor of 5/3, or 1.67, was applied to each instance in which a terrestrial focus group was cited for a need or activity area (i.e., 1 terrestrial citation*1.67 weighting = 1.67 weighted citations). The order in which activity areas are listed in this table reflects the weighting. The absolute value of # of citations is also reflected in the two right-hand columns (out of 17 venues).*

Need or Activity Area (Chapter # and Section #)	# of citations* (out of 19)	# of citations (out of 17)	Distribution of citations by ecosystem-based focus group and workshop
Most frequently cited (>50% of weighted venues)			
Decision-support systems and tools (III.1)	19	17	Cited in all venues
Collaboration and other capacity-building activities (III.2)	16.3	15	5 of 5 marine 4 of 5 freshwater 2 of 3 terrestrial 3 of 3 workshops
New or different science, data, or information (III.3)	16.3	15	5 of 5 marine 4 of 5 freshwater 2 of 3 terrestrial 3 of 3 workshops
Increase the resiliency of the hydrologic regime to climate change and other stressors (V.1)	14.3	13	3 of 5 marine 4 of 5 freshwater 2 of 3 terrestrial 3 of 3 workshops
Track climate change effects and compare management options in the marine nearshore and estuarine environment (VI.1)	11.7	11	5 of 5 marine 1 of 5 freshwater 1 of 3 terrestrial 3 of 3 workshops
Science communication and outreach (III.4)	11	11	5 of 5 marine 3 of 5 freshwater 0 of 3 terrestrial 2 of 3 workshops
Support efforts to identify the dispersal corridors invasive species, pests, pathogens, and diseases are likely to use in response to changes in climate (IX.1)	10.3	9	3 of 5 marine 1 of 5 freshwater 2 of 3 terrestrial 2 of 3 workshops
Assess the vulnerability of Pacific salmon, other anadromous fish, and their habitats to climate change effects (VIII.1)	10	10	2 of 5 marine 4 of 5 freshwater 0 of 3 terrestrial 3 of 3 workshops
Second most-frequently cited (30-49% of weighted venues)			
Need or Activity Area (Chapter # and Section #)	# of citations* (out of 19)	# of citations (out of 17)	Distribution of citations by ecosystem-based focus group and workshop
Support the efforts of Tribes, Native Alaskans, and First Nations to identify and address climate-related priorities related to decision-support and capacity-building (IV.1)	9	9	3 of 5 marine 2 of 5 freshwater 0 of 3 terrestrial 3 of 3 workshops
Address climate change effects on large landscapes, especially whole-scale changes in vegetation composition (VII.1)	8.3	7	1 of 5 marine 2 of 5 freshwater 2 of 3 terrestrial 1 of 3 workshops

Identify, protect, and maintain the integrity of connectivity and refugia networks in light of climate change effects (VII.2)	8.3	7	1 of 5 marine 1 of 5 freshwater 2 of 3 terrestrial 2 of 3 workshops
Address potential changes in phenology and food webs due to acidified and low-oxygen ocean conditions (VI.2)	7	7	3 of 5 marine 0 of 5 freshwater 0 of 3 terrestrial 3 of 3 workshops
Conduct research to understand and assess climate change effects on the Indigenous Way of Life (IV.2)	6.7	6	1 of 5 marine 2 of 5 freshwater 1 of 3 terrestrial 2 of 3 workshops
Study the interaction of fire with other disturbance regimes given current and potential future climate change effects (VII.3)	6.3	5	0 of 5 marine 0 of 5 freshwater 2 of 3 terrestrial 2 of 3 workshops
Characterize eelgrass and kelp habitats and identify priority areas (VI.3)	6	6	4 of 5 marine 0 of 5 freshwater 0 of 3 terrestrial 2 of 3 workshops
Generate research and models for forage fishes (VIII.2)	6	6	4 of 5 marine 0 of 5 freshwater 0 of 3 terrestrial 1 of 3 workshops
Third most-frequently cited (<30% of weighted venues)			
Need or Activity Area (Chapter # and Section #)	# of citations* (out of 19)	# of citations (out of 17)	Distribution of citations by ecosystem-based focus group and workshop
Identify focal indicators to track climate change and assess management options (VIII.3)	5.7	5	0 of 5 marine 1 of 5 freshwater 1 of 3 terrestrial 2 of 3 workshops
Inform cost estimates and vulnerability assessments related to altered coastal flooding regimes in Puget Sound and the California Current Region (VI.4)	4	4	1 of 5 marine 1 of 5 freshwater 0 of 3 terrestrial 1 of 3 workshops
Conduct more and better coordinated assessments of climate change effects on fog patterns and forest hydrology in northwestern California (VII.4)	2.7	2	0 of 5 marine 0 of 5 freshwater 1 of 3 terrestrial 1 of 3 workshops
Support to advance efforts to address climate change in the Willamette Valley, Oregon (ViI.5)	2.7	2	0 of 5 marine 0 of 5 freshwater 1 of 3 terrestrial 1 of 3 workshops
Develop maps and models to address climate change effects on other key fish species (VIII.4)	2	2	1 of 5 marine 0 of 5 freshwater 0 of 3 terrestrial 1 of 3 workshops

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I. Introduction

The purpose of this report is to identify challenges, needs, and opportunities associated with managing ecosystems, habitats, species, and indigenous resources in light of current and projected climate change effects in the North Pacific Landscape Conservation Cooperative (NPLCC) region. The report compiles input from climate change, conservation, and resource management professionals who work throughout the NPLCC region. The report is intended to advance NPLCC goals, especially the goal to:

> *Maximize the ability of partners, constituents, and stakeholders to make good conservation and sustainable resource management decisions under a changing climate…by providing…the right information (spatial or non-spatial data, TEK, case studies of adaptation action, etc.) at the right scale in the right way at the right time, and the tools, perspectives, and support needed to make appropriate use of the information (S-TEK Subcommittee Meeting, April 5, 2012).*

More specifically, the results are intended to inform development of the NPLCC Strategy for Science and Traditional Ecological Knowledge (2013-2016; hereafter, S-TEK Strategy) and the S-TEK"s annual work plans.

The report analyzes, synthesizes, and presents the input of 195 resource managers, conservation practitioners, and researchers working at the nexus of climate change and ecosystem response in the NPLCC region. The information was collected through surveys, web-based focus groups, and in-person workshops between December 2011 and June 2012. This report also incorporates findings from similar needs assessments found in the scientific and grey literature.

It is our hope this report will facilitate effective landscape-scale climate change adaptation, conservation, and sustainable resource management by providing useful information to NPLCC members and stakeholders, connecting NPLCC members and stakeholders with those who may be able to assist them in their efforts to address climate change, and informing the NPLCC"s strategic planning processes.

The NPLCC Region

The NPLCC region extends from southcentral Alaska to northwest California and comprises approximately 204,000 square miles (530,000 square kilometers, km^2) in seven western U.S. states and Canadian provinces (Figure 1, p. 5).[58] There are four biogeoclimatic rainforest zones in the region, each distinguished by their subregional climate, vegetation, soils, and disturbance regimes.[59] From north to south, they are the subpolar zone, perhumid zone, seasonal zone, and warm zone.[60] The region is characterized by strong linkages among its marine, freshwater, and terrestrial ecosystems, key species such as salmon that connect those ecosystems, and strong cultures that depend upon healthy, resilient habitats.

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[58] US FWS (2010b). Within the Yukon Territory (YT; 186,272 mi^2, 482,443 km^2), land within the NPLCC region is in southwest YT, the Kluane National Park and Preserve (8,487 $miles^2$, 21, 980 km^2; ~4.6% of total area in YT).

[59] Alaback and Pojar (1997)

[60] Alaback and Pojar (1997)

The total amount of coastline is approximately 38,200 miles (~ 61,500 km)[61] and encompasses picturesque waterways such as Alaska‟s Inside Passage and Puget Sound in the Pacific Northwest. The region‟s coastal waters and lands provide an array of ecosystem services including commercial and subsistence harvest, recreational fishing and gathering opportunities, and protection from storms and flooding.

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 such as the Copper River Watershed, Stikine Watershed, Fraser Basin, Columbia River Basin, and Klamath Basin are included within the area. These watersheds provide fresh water for millions of people and wildlife, are a key sediment source for the region‟s many estuarine ecosystems, and support vast tracts of temperate forest ecosystems.

Public lands make up approximately 78 percent, or 159,000 square miles (412,000 km^2) of the NPLCC, with 82,000 square miles (212,000 km^2) of Federal lands in the U.S. portion of the NPLCC and 77,000 square miles (200,000 km^2) of Crown lands in the Canadian portion of the NPLCC.[62] Temperate coniferous and boreal forests dominate the landscape and are among the last-remaining, intact forests of their kind in the world.[63] The connection among the region‟s marine, freshwater, and terrestrial ecosystems is evident in these forests – the same salmon that return from the sea to their natal freshwater habitats also nourish the forest, provide food for iconic species such as grizzly bear, and are critical to the Way of Life for many Tribes, First Nations, and Native Alaskans.

Organization of Report

The Executive Summary summarizes the major points of the assessment, specifically four core needs for science and traditional ecological knowledge in the NPLCC region and seventeen activity areas specific to ecosystems, habitats, species, and indigenous resources. The Introduction and Methodology (Chapters I and II, respectively), provide a framework within which to consider the assessment‟s findings by reviewing the project‟s purpose, key information about the NPLCC, and the methods used to acquire, analyze, and synthesize results. Key findings are found in Chapters III-IX, which describe the four core needs identified in the NPLCC region, then provide specific examples of those needs for the region‟s indigenous natural and cultural resources and freshwater, coastal, and terrestrial ecosystems, habitats, and species. A conclusion and description of next steps are provided in Chapter X. Chapter XI includes five appendices: a list of project participants and primary affiliations, a bibliography, a technical supplement to the methodology, a copy of the survey instrument, and examples of discussion questions used in the web-based focus groups.

Direct quotes from survey respondents are *italicized* with quotation marks around them. Web-based focus group input from the transcripts is *italicized* with the focus group identified parenthetically (see Table 6, p. 14 for a list of the focus groups), but does not include quotation marks because the information was transcribed in a nearly verbatim fashion. Therefore, the transcripts are faithful representations of participant comments, but are not full verbatim quotes.

[61] US FWS (2010b)
[62] US FWS (2010b)
[63] DellaSala (2011), Olson et al. (2001)

A note on the partners and ongoing efforts identified in this report: We encouraged participants to be as specific as possible when identifying partners and ongoing efforts. In some cases, participants identified individuals as potential partners or contacts, while in others, only organizations or programs were identified. However, **the partners and ongoing efforts identified in the report should not be considered comprehensive.** We welcome and encourage further additions to the partners and ongoing efforts included in the report. **Please contact Patricia Tillmann** (tillmannp@nwf.org) **or Mary Mahaffy** (Mary_Mahaffy@fws.gov) **to make a suggestion.**

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Barbara Schrader	Alaska Region Vegetation Ecologist, U.S. Forest Service
Bruce Harrison	Head of Conservation Science and Planning, BC, Ducks Unlimited Canada
Bruce Stein	Director for Climate Change Adaptation, National Wildlife Federation
Dominick DellaSala	President and Chief Scientist, Geos Institute
Garrit Voggesser	National Director for Tribal Partnerships, National Wildlife Federation
James Casey	Freshwater Conservation Analyst, WWF-Canada
John Morton	Supervisory Fish & Wildlife Biologist, Kenai NWR, U.S. Fish and Wildlife Service
Karen Thorne	PhD, Research Ecologist, USGS Western Ecological Research Center
Kathy Lynn	Tribal Climate Change Project Coordinator, University of Oregon
Lara Whitely Binder	Outreach and Adaptation Specialist, Climate Impacts Group
Leihla Scharlau	South Sound Estuary Association
Lyman Thorsteinson	Senior Science Advisor, U.S. Geological Survey Alaska Area
Marc Nelitz	Senior Systems Ecologist, ESSA Technologies Ltd.
Paul Pickett	Washington State Department of Ecology
Rowan Baker	U.S. Fish and Wildlife Service
Winston Smith	Principal Research Scientist, University of Alaska Fairbanks

And we are indebted to the 195 individuals who gave generously of their time and knowledge to participate in the surveys, focus groups, and workshops. Their efforts made this report possible and have advanced knowledge of the challenges, needs, and opportunities conservation, climate change, and resource management professionals see in their efforts to address climate change in daily work and long-range planning. Project participants are listed in Appendix 1, p. 175.

Suggested Citation

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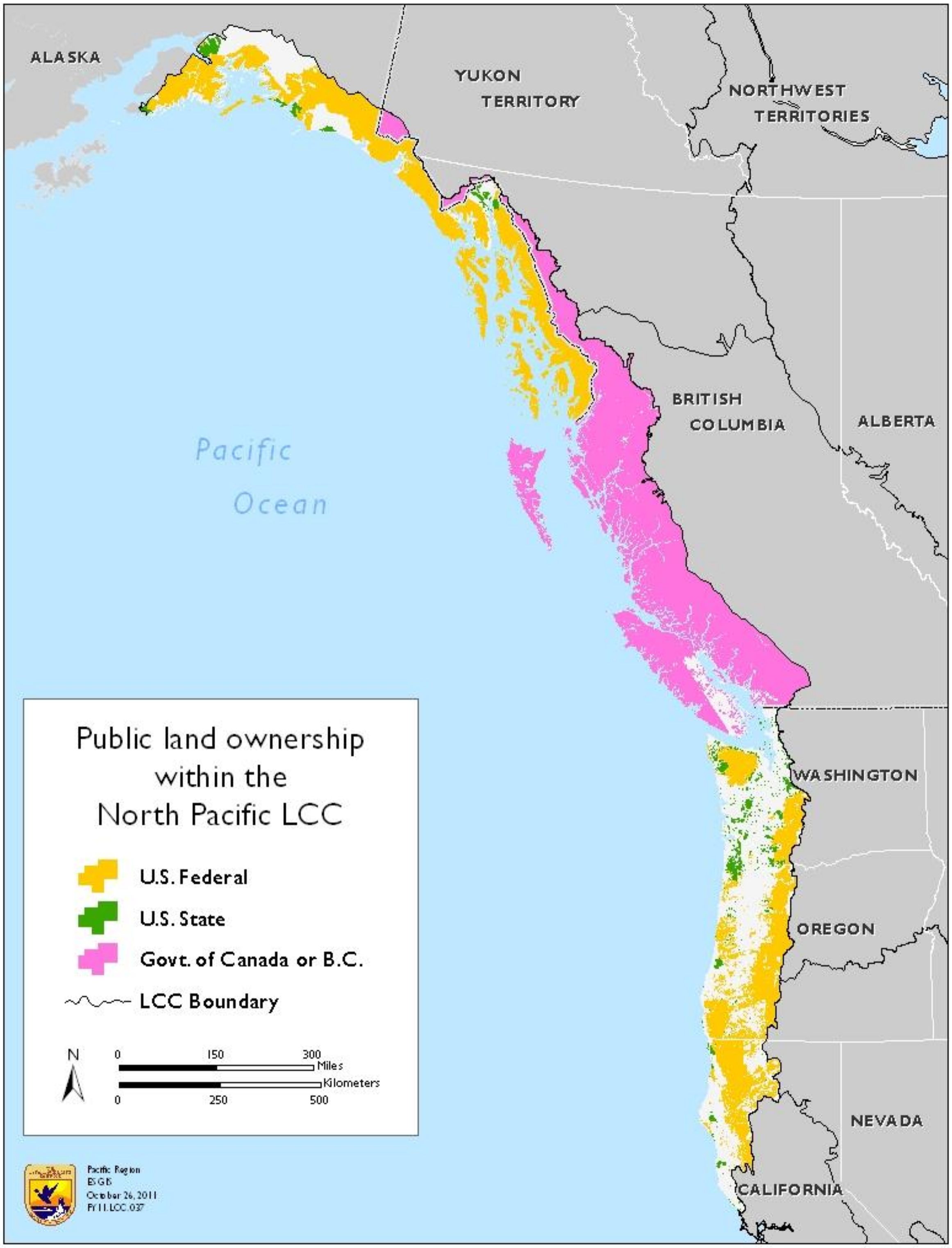

Figure 1. Public land ownership within the North Pacific Landscape Conservation Cooperative (NPLCC). *Source: U.S. Fish and Wildlife Service (2011). This is a preliminary land ownership map, including only federal, state, and provincial lands. At a later date, the map will be updated to include Native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

II. Methodology

To achieve the project goal of identifying climate change-related challenges, needs, and opportunities associated with conserving and managing ecosystems, habitats, species, and indigenous resources in the NPLCC region, we investigated three research questions:

1. What are the challenges, needs, and opportunities for conservation, climate change, and resource management professionals working at the nexus of climate change impacts, adaptation, and ecosystem response to manage marine, freshwater, and terrestrial ecosystems, habitats, and species in light of current and projected climate change impacts in the NPLCC region? Climate change, conservation, and resource management professionals include those from Federal, state, and Tribal agencies, non-governmental organizations, and universities in the NPLCC region.
2. What is the decision-relevance, spatial scale, temporal scale, timeline, and sense of urgency for the challenges, needs, and opportunities identified in Research Question #1?
3. Which partners and ongoing efforts are currently available to assist with addressing the challenges, needs, and opportunities identified in Research Question #1?

A combination of surveys, semi-structured interviews, web-based focus groups, and in-person workshops were used to investigate these questions. Each of these venues provided an opportunity for conservation, climate change, and resource management professionals working in the NPLCC region to share with the NPLCC the challenges, needs, and opportunities for NPLCC support they see with regard to climate change effects on their work. In each venue, project participants identified climate change-related science, management and traditional ecological knowledge challenges and needs, key characteristics of the needs, the tools and other support to meet those needs, and opportunities related to advancing landscape-scale conservation and sustainable resource management in light of climate change.

Approach

To our knowledge, no assessment of climate change-related management challenges, opportunities, and needs had been completed particular to the NPLCC region and its ecosystems prior to commencing this project. As the first study to address these questions at this scale, we applied the *grounded theory approach to qualitative data analysis* (Box 2, p. 10) to inform the design of this study and analyze results. The grounded theory approach suggests it is most appropriate to begin with an open-ended, exploratory approach that allows project participants to share their experiences with as little influence from the investigators as is possible, then proceed to more structured approaches to examine and interpret data to elicit meaning and generate an understanding of the themes, concepts, and potential needs in the region emerging from responses (Corbin and Strauss 2008, p. 1). This approach minimizes the influence of *a priori* biases held by the researcher on the research findings and enables the perspectives and expertise of participants to determine research findings (Corbin and Strauss 2008). We also followed the principles of *applied policy research*[64] by emphasizing transparency in data generation and assessment, for example by

[64] *Applied policy research* is characterized by methods designed to meet pre-determined objectives shaped by specific information requirements in a decision making process. Research is typically conducted in teams over shorter timelines (months rather than years), involves the generation of new data using interviews, group discussions, or observational work, and emphasizes transparency and making data available in a form that is useful and relevant for decision makers. These methods respond to the short-term deadlines and need for transparency

making all transcripts, proceedings, and other products available to project participants. Finally, through the survey and interview responses, web-based focus group input, and workshop results, the project generated new data on climate-related challenges, needs, and opportunities to inform key decision points in the NPLCC‟s decision making process, namely the development of the S-TEK strategy. This is also a defining feature of applied policy research (Ritchie and Spencer 2002).

This report provides results from the second phase of a two-phase effort to compile climate change-related science and adaptation strategies and identify key gaps regarding conservation and management of ecosystems, habitats, and species in the NPLCC region. During Phase I (initiated in October 2010), we produced two draft final reports compiling information from the scientific and grey literature on climate change effects and adaptation approaches for the region‟s marine/coastal and freshwater systems.[65] Sufficient resources were not available at that time to include terrestrial systems. This project (Phase II; see Table 4, p. 12) began in September 2011, and initially built on Phase I‟s focus on marine/coastal and freshwater systems. Subsequently, the NPLCC awarded additional funds in March 2012 to include terrestrial systems for both the compilation of science and the assessment of climate change-related challenges, needs, and opportunities for advancing landscape-scale conservation and sustainable resource management. Thus, this Phase II report is an assessment and synthesis of the climate change-related challenges, needs, and opportunities identified by professionals working in the full range of marine/coastal, freshwater, and terrestrial systems throughout the NPLCC region.[66]

In August 2012, a draft report was released for review. Comments from 16 reviewers were incorporated to produce the final report. A summary of the sampling method, analysis, and results is included here; a more detailed Technical Supplement, which includes definitions for the sampling methods and an example of the coding used to identify themes, is provided in Appendix 3 (p. 188).

Sampling Method

Consistent with the exploratory nature of the research, we began by using *purposive* and *network sampling methods* to identify prospective project participants (Neuman 2004). Through this process we identified 396 prospective participants that met our criteria: the network of staff from federal, state, and tribal agencies, conservation and climate change NGOs, and university scientists addressing climate change in their ecosystem, habitat, and species-related work in the NPLCC region. Specifically, we first queried our NPLCC contacts database for those who had been previously contacted to participate in projects focusing on the NPLCC region by National Wildlife Federation, the U.S. Fish and Wildlife Service, or the NPLCC. We also queried our NPLCC contacts database for those who have specific expertise in climate change and ecosystem, habitat, and/or species response. The initial list was distributed to the NPLCC S-TEK Subcommittee, NPLCC Steering Committee, and well-networked individuals in the region via email with a request to suggest additional participants and further distribute among their networks to identify additional participants. Where gaps remained in representation of ecosystems, habitats, or species, we conducted interviews with several individuals to identify additional prospective project participants. We also reviewed staff profiles at federal and state agencies, universities,

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associated with informing key activities or decision points in a decision making process. Source: Ritchie and Spencer (2002).

[65] Tillmann & Siemann (2011a, 2011b)

[66] Final compilations of scientific literature (Phase I reports) for marine, freshwater, and terrestrial systems are planned to be completed by October 2013.

conservation and climate change NGOs, and tribally affiliated organizations to identify participants and fill gaps in representation of location or expertise (see footnote for example list).[67] Through this process, we targeted the sample population of interest and the number of new names we received diminished over time, indicating the purposive and network sampling methods targeted the network of interest.

Of the 396 prospective project participants, 195 participated through one or more methods, including a series of surveys, web-based focus groups, semi-structured interviews and in-person workshops (response rate: 49%). Project participants were well-distributed across the NPLCC region, ranging from twenty-six participants from British Columbia (13.3%) to 36 participants from California (18.5%; see Table 2 below). Project participation was dominated by those employed with U.S. federal agencies (~38%, or 74 participants),[68] followed by non-governmental organizations (45 participants, 23.1%) and Tribes, First Nations, and Alaska Native communities (29 participants, 14.9%; see Table 3 on next page).

In December 2011, January 2012, and May 2012, web-based surveys were distributed to ~300 land and resource managers, scientists, and conservation practitioners working in federal, state, provincial, and tribal agencies, NGOs, and universities in the NPLCC region (response rate: ~25%, n=79). The survey was comprised of ten open-ended questions that asked respondents to briefly describe their work, how climate change affects their work, the challenges presented by climate change, and any current or future opportunities to address climate change in their work (see Appendix 4. Survey Instrument, p. 197).

Table 2. Distribution of Project Invitees and Participants, by primary location

	Invited	% of total invited	Attended	% of total attended
Alaska	52	13.1	31	15.9
British Columbia	65	16.4	26	13.3
Washington	79	19.9	36	18.5
Oregon	67	16.9	29	14.9
California	67	16.9	36	18.5
Tribes, Alaska Natives, First Nations	50	12.6	27	13.8
Other	16	4.0	10	5.1
COLUMN TOTAL	396	100.0	195	100.0

[67] Staff profiles were reviewed at many organizations including the Oregon Climate Change Research Institute, University of Washington Climate Impacts Group, Pacific Northwest and Pacific Southwest Research Stations of the U.S. Forest Service, USGS Water Science Centers, USGS Western Ecological Research Center, Canada Department of Fisheries and Oceans, Parks Canada, British Columbia Ministries of Environment and Forests, Lands, and Natural Resource Operations, fish, wildlife, game, natural resource, parks, and ecology agencies in Alaska, Washington, Oregon, and California, Alaska Coastal Rainforest Center, EcoAdapt, Conservation Northwest, The Nature Conservancy, Geos Institute, Conservation Biology Institute, Stillwater Sciences, ESSA, West Coast Aquatic Management Board, World Wildlife Fund – Canada, Columbia River Intertribal Fish Commission, Northwest Indian Fisheries Commission, Central Council Haida and Tlingit Tribes of Alaska, and Coastal First Nations.

[68] This is consistent with approximately 40% of land in the U.S. portion of the NPLCC region (82,000 of approximately 204,000 square miles) being under the jurisdiction of U.S. federal agencies (see US FWS, 2010b).

Table 3. Distribution of Project Invitees and Participants, by type of organization or government				
	Invited	% of total invited	Attended	% of total attended
Academia	43	10.9	19	9.7
Federal (U.S. and Canada)[69]	179	45.2	79	40.5
NGO/Other	73	18.4	45	23.1
State/Provincial	44	11.1	23	11.8
Tribes, First Nations, and Alaska Native Communities	57	14.4	29	14.9
COLUMN TOTAL	396	100.0	195	100.0

In January, February, and May 2012, 107 individuals participated in one or more of thirteen web-based focus groups designed to better articulate and understand climate change-related management challenges and opportunities in marine, coastal, freshwater, and terrestrial ecosystems located in distinct biogeophysical subregions of the NPLCC (response rate: ~29%). Participants selected the focus group(s) in which they participated based on their expertise and interest in marine, coastal, freshwater, and/or terrestrial ecosystems, habitats, and species, as well as the biogeophysical focus of the focus group (Table 6, p. 14). Specifically:

- The five marine and coastal ecosystem focus groups were organized to focus on southcentral and southeast Alaska, the British Columbia coast, Puget Sound and Georgia Basin, and the California Current Region (79 participants in all).
- The five freshwater and riparian ecosystem focus groups were organized to focus on the Alaska and British Columbia coast, the Pacific Coast and Nass Ranges, Puget Sound and Georgia Basin, Columbia River Basin, and the coastal drainages of Washington, Oregon, and California (29 participants in all).
- The three terrestrial ecosystem focus groups were organized to focus on coastal temperate rainforests, the interior mountains, and lowlands, prairies and other non-forested systems (31 participants in all).

Although funding limited the number of terrestrial focus groups to three instead of five, the number of participants across the focus groups indicates comparable representation for freshwater- and terrestrial-focused web-based focus groups and strong representation for marine- and coastal-focused web-based focus groups.

To augment, refine, and build on the survey and focus group results, three one-day in-person workshops were held in Portland, Oregon (Feb. 28, 2012; 39 participants), Juneau, Alaska (April 20, 2012; 43 participants), and Arcata, California (June 11, 2012; 29 participants) (Tables 7-8, p.15-16). These workshops focused on identifying NPLCC-wide needs that, if fulfilled, would advance efforts to address climate change in participants‟ work.

Across the web-based focus groups and in-person workshops, there is an emphasis on marine- and coastal-focused topics: most web-based focus group participants participated in marine- and coastal-

[69] Most participants from federal agencies (74 of 79, or ~38% of all 195 project participants) are employed with U.S. federal agencies. Approximately 40% of the land in the U.S. portion of the NPLCC region is also under the jurisdiction of U.S. federal agencies (see US FWS, 2010b).

focused meetings (Table 6, p. 14) and in-person workshop topics are also marine- and coastal-focused (Tables 7-8, p. 15-16). This indicates marine- and coastal-focused topics were strongly-represented compared to freshwater-, multi-ecosystem, and terrestrial-focused topics. Since the frequency analysis (see next section and Appendix 3. Technical Supplement, p. 188) is based on the number of venues in which a particular need or activity area was cited and because three web-based focus groups were convened for terrestrial systems versus the five convened for marine/coastal and freshwater systems each, a weighting factor of 1.67 was applied to each mention of terrestrial focus groups to normalize results across all web-based focus groups.

Data Analysis and Results

We used the grounded theory approach to qualitative data analysis to analyze survey responses, web-based focus group input, and in-person workshop results (Box 2). Survey questions and facilitated focus group discussions focused on identifying the challenges, opportunities, and needs associated with managing ecosystems, habitats, and species in light of current and projected climate change effects. Several themes reflecting the challenges, opportunities, and needs associated with addressing climate change effects emerged from the initial analysis of survey response data (Table 5, p. 13). The initial themes were tested and refined by participants, first during the web-based focus groups and again during the in-person workshops. The in-person workshops also provided participants the opportunity to evaluate the needs identified through the survey and focus group processes, as well as additional needs identified during the workshops themselves, across the four criteria listed in Research Questions 2 and 3. Specifically, participants assessed the decision-relevance, spatial scale, temporal scale, timeline, and sense of urgency for each need. They also identified partners and ongoing efforts that may be able to assist with addressing the need.

After each focus group or workshop, the authors and their partners reflected on the discussion to articulate new insights and identify topics to investigate further in subsequent meetings. This iterative process identified new concepts to explore and provided new meaning for previously identified concepts, challenges, and needs. In

Box 2. The Grounded Theory Approach to Qualitative Data Analysis

The *grounded theory approach to qualitative data analysis* is a specific methodology for "building theory from data" (Corbin and Strauss 2008, p. 1). Data are collected through surveys, interviews, and other methods. Surveys are well-suited to answering research questions such as ours, which ask "who, what, where, how many, and how much." Three stages of coding allow themes held within data to emerge in a meaningful way:

- *Open coding* identifies concepts that seem important given the context of the interview or survey. Initial concepts often proliferate and are organized into categories. "Capacity" is an example of a category that encompasses open codes related to training, funding, time, and personal knowledge.
- *Axial coding* relates categories according to their structure and process, thereby identifying major research themes. Structure describes the "why" and process describes the "how" of the relationships among categories. Table # in Appendix # provides an example of open and axial coding.
- *Selective coding* identifies specific cases that effectively illustrate the themes identified through axial coding, thereby providing supporting evidence for research findings. In this report, these are the survey responses, excerpts from web-based focus group transcripts, and worksheet comments used to illustrate themes and concepts.

Sources: Corbin & Strauss (2008). Neuman (2004). Strauss & Corbin (1998). Yin (2003).

addition to the qualitative analysis of survey responses, formal qualitative analysis of focus group and workshop input occurred at two points: after the completion of the aquatic focus groups and Portland workshop (Tillmann & Siemann 2012), and again after all focus groups and workshops were complete.

Approximately forty initial concepts and themes were identified; examples are provided in Table 5, p. 13 and Table 9, p. 195. These describe the array of tools, information, and related assistance project participants documented as needs. Through the iterative process of discussion and qualitative data analysis, these initial concepts and themes were synthesized and partitioned into four discrete needs: (1) decision-support systems and tools, (2) collaboration and other capacity-building activities, (3) new or different science, data and information, and (4) science communication and outreach (please see Appendix 3, Table 9, p. 195 for an example of the analytical coding process). Within each of these four core needs, there are many examples specific to ecosystems, habitats, species, and indigenous resources. To accurately and completely capture these examples, the same analytic approach used to identify the four core needs was applied to group the multitude of examples into seventeen distinct activity areas that capture the range and diversity of ecosystem-, habitat-, species-, and resource-specific requests made by project participants. Within an activity area, specific projects, activities, or other requests identified by project participants are described and participant evaluations of decision-relevance, spatial and temporal scale, timeline and sense of urgency, and partners and ongoing efforts are summarized. Finally, after all data analysis was complete, the four needs and seventeen activity areas were ranked according to the frequency across venues (recall that the venues are the survey, web-based focus groups, and in-person workshops) with which project participants identified a particular need or activity area. To account for the fact that three web-based focus groups were convened for terrestrial systems instead of the five that were convened for marine/coastal and freshwater systems, a weighting factor of 1.67 was applied to each instance in which a terrestrial focus group was cited for a need or activity area.[70] This normalizes results across focus groups.

Discussion

This study engaged a broad range of conservation, climate change, and resource management professionals working at the nexus of climate change and conservation in the NPLCC region, but as the first assessment of its kind, this synthesis should not be considered completely comprehensive. It is most representative of the 195 people who participated in the project. Results are well-distributed by location and strongly representative of marine- and coastal-focused topics. Two assessments similar to this one have been conducted for marine and coastal ecosystems (NOAA 2011, Finzi Hart 2012). These needs assessments identified many of the challenges, needs, and opportunities included in this report and are a source of external support for the findings reported herein. We encourage repeating and building from these efforts to augment and revise our findings as appropriate, with specific attention to freshwater, terrestrial, and multi-ecosystem topics. Please see Appendix 1 (p. 175) for a list of project participants and Appendix 3 (p. 188) for a Technical Supplement with additional information on the methodology.

[70] Mathematically, $3x=5$, where $x=5/3=1.67$ is the weighting factor to normalize the three terrestrial ecosystem focus groups with the five focus groups each for marine/coastal and freshwater ecosystems. Therefore, for each citation of a terrestrial focus group, 1 terrestrial citation*1.67 weighting = 1.67 weighted citations.

Table 4. Summary of Project Approach		
Timeline 9/2011 – 12/2012	***Goal & Activities***	***Participants in NPLCC Region***
TIERS 1 & 2: IDENTIFY SAMPLE POPULATION, DISTRIBUTE SURVEY & ANALYZE RESPONSES		
September through November 2011	Project planning. Identify participants using purposive, network methods. Develop survey instrument.	National Wildlife Federation (NWF), University of Washington Climate Impacts Group (CIG)
December 2011, January 2012	Web-based surveys to acquire information about participants‟ professional responsibilities, how climate change affects their work, and the challenges, opportunities, and needs presented by climate change in their work	Land and resource managers, scientists, and conservation practitioners working in federal, state, provincial, and tribal agencies, NGOs, and universities.
December 2011 through February 2012	Qualitative analysis of survey results using grounded theory to generate key concepts and themes that describe challenges, opportunities, and needs associated with addressing climate change in respondents‟ work. Develop more focused questions for Tier 3.	NWF and CIG
TIER 3: CONVENE WEB-BASED FOCUS GROUPS & SEMI-STRUCTURED INTERVIEWS, ANALYZE INPUT		
January, February, April, and May 2012	Web-based focus groups to probe concepts and themes identified through the survey and acquire additional information on decision-relevance. The geographic focus was the sub-NPLCC scale to capture information particular to participants‟ location. Interviews with terrestrial experts to identify and discuss potential concepts, themes, and needs for terrestrial ecosystems.	Land and resource managers, scientists, and conservation practitioners working in federal, state, provincial, and tribal agencies, NGOs, and universities.
February-May 2012	Transcription and analysis of web-based focus group input to determine which concepts, themes, and categories of information needs emerged most frequently across focus groups or repeatedly within a focus group. Generate discussion topics for in-person workshops.	NWF and CIG
TIER 4: CONVENE IN-PERSON WORKSHOPS & SEMI-STRUCTURED INTERVIEWS, ANALYZE INPUT		
February 28, 2012 April 20, 2012 June 11, 2012	In-person workshops to identify particular needs that, if fulfilled, would advance the ability to address climate change impacts in the NPLCC region. Interviews with terrestrial experts to identify and discuss potential concepts, themes, and needs for terrestrial ecosystems.	Land and resource managers, scientists, and conservation practitioners working in federal, state, provincial, and tribal agencies, NGOs, and universities in the NPLCC region.
TIER 5: ANALYZE & SYNTHESIZE ALL INPUT TO PRODUCE REPORT		
June-Sep 2012	Analysis and synthesis of survey responses, transcripts of web-based focus groups, and worksheets from in-person workshops to produce draft report of climate-related challenges, opportunities, needs, and potential science and TEK priorities in NPLCC region. Review of draft.	NWF produces draft with input from partners. All 195 project participants, CIG, the NPLCC, and other stakeholders are invited to review draft report. 16 people review report.
Aug-Dec 2012	Incorporate reviewer input to produce final report.	NWF and partners.

Table 5. Concepts and Themes Representing Climate-related Management Challenges and Opportunities Identified through the Analysis of Survey Results	
Climate-related Management Challenges	***Climate-related Management Opportunities***
1. Difficult to identify, understand, and use climate change science, data, tools, and/or information	1. Develop and generate new or different science, data, and information
2. Insufficient human, financial, technical, political, and institutional capacity	2. Build capacity of people as well as financial, technical, political, and institutional systems
3. Institutional, international, political, cultural, and/or social barriers inhibit efforts to address climate change	3. Facilitate coordination, collaboration, and communication among people, projects, institutions, and funding
4. Inadequate coordination, collaboration, and communication among people, projects, institutions, and funding	4. Develop management, policy, and/or recommendations
5. Difficult to incorporate or address uncertainty	5. Create visual depictions of climate change effects and response options
6. Climate-related priorities compete with other priorities and climate change has not been mainstreamed sufficiently into current environmental priorities	6. Develop and compare tools on climate change effects and response options, and for other decision-support
	7. Provide guidance on climate change effects, response options, and tools
	8. Generate benefit-cost analyses, cost estimates, and tradeoffs
	9. Develop or modify a climate clearinghouse of people, projects, and/or literature

Table 6. Biogeophysical Organization and Attendance for Web-based Focus Groups[71]

Attendance	Biogeophysical Organization	
Marine/Coastal Ecosystem Focus Groups (Subtotal: 79 participants)	**Ecoregions Included in Each Web-based Focus Group**	**Map of Ecoregions in NPLCC Region**
1. Southcentral and Southeast Alaska (n=11)	Coastal W. Hemlock-Sitka Spruce, Pacific Coast Mountains	
2. British Columbia Coast (n=24)	Coastal W. Hemlock-Sitka Spruce	
3. Puget Sound and Georgia Basin (n=16)	Strait of Georgia/Puget Lowland	
4.& 5. California Current (n=28)	Coast Range	
Freshwater Ecosystem Focus Groups (Subtotal: 29 participants)		
1. Alaska and British Columbia Coast (n=8)	Coastal W. Hemlock-Sitka Spruce	
2. Pacific Coast and Nass Ranges (n=4)	Pacific Coast Mountains, Pacific & Nass Ranges	
3. Puget Sound and Georgia Basin (n=7)	Strait of Georgia/Puget Lowland	
4. Columbia River Basin (n=2)	Cascade Mountains, Willamette Valley	
5. WA/OR/n. Coastal Ranges and Drainages (n=8)	Coast Range, Klamath Mountains	
Terrestrial Ecosystem Focus Groups (Subtotal: 31 participants)		
1. Coastal Temperate Rainforests (n=20)	Coastal W. Hemlock-Sitka Spruce, Pacific Coast Mountains, Coast Range	
2. Lowlands, Prairies, and Other Non-forested Systems (n=6)	Willamette Valley, Strait of Georgia/Puget Lowland	
3. Interior Mountains (n=5)	Pacific & Nass Ranges, Cascade Range, Klamath Mountains	

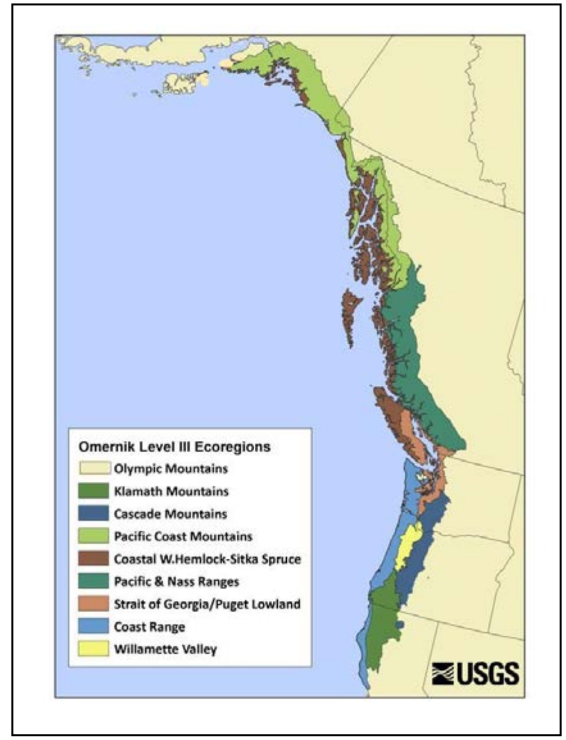

Image Source: Woodward, Taylor, and Weekes (2012)

[71] 107 individuals participated in one or more web-based focus groups (response rate: ~29%). Therefore, the sum of "n" (N=139) is greater than the total number of individuals.

Table 7. In-person Workshop Attendance (N=111)[72]								
Primary Affiliation	Portland (n=39)		Juneau (n=43)		Arcata (n=29)		Subtotal by Primary Affiliation	
	# people	~%	# people	~%	# people	~%	# people	~%
Tribes Alaskan Natives First Nations	1	2	**19**	**44**	6	21	26	24
Federal	**24***	**62**	15	35	**12**	**42**	**51**	**46**
State	5	13	0	0	3	10	8	7
Academia	2	5	5	12	3	10	10	9
NGO/other	7	18	4	9	5	17	16	14
***Bolded** entries indicate the primary affiliation with the greatest number and associated percentage of participants for a given column (Portland, Juneau, Arcata, Subtotal by Primary Affiliation).								

[72] Three individuals attended two workshops. Therefore, 108 individuals participated in one or more workshops (response rate: ~29%).

Table 8. List of Potential Information Needs Discussed in Each In-person Workshop

Science-based			Science-Support
Portland	Juneau	Arcata	All Workshops
1. Climate-smart sensor network 2. Sedimentation and tidal elevation data 3. Coldwater and forage fishes 4. Ocean acidification, hypoxia and food web impacts 5. Eelgrass and kelp 6. Invasive species and disease 7. Cumulative impacts of climate change on coastal habitat type and distribution	1. Marine & aquatic organisms, range shifts, food web impacts, and distribution 2. Habitat and species effects of reduced glacier size/abundance & changing glacial hydrology 3. Freshwater and marine wetlands/estuarine habitats, soils, and terrestrial/marine nutrient cycling and carbon (including bogs and peatlands) 4. Aquatic and terrestrial invasive species and disease/pathogens 5. Impacts of climate change on island ecosystems 6. Changes in terrestrial vegetation/habitat and food webs/distribution	1. Climate change effects on fog, hydrology & disturbance regimes, & resulting effects on forest distribution & mortality a. Fog and hydrology sub-group b. Disturbance sub-group *2. Invasive species (not done)* 3. Effects of climate-related changes to disturbance regimes on terrestrial/riparian birds, amphibians, and/or mammals 4. Effects of climate change on wetlands and rangelands 5. Climate change effects on corridor/refuge ID, access mgmt, & strategic land acquisition	1. Assistance identifying or using tools, including training 2. Enhanced coordination, collaboration, and communication 3. Address institutional, international, political, cultural, and social barriers 4. Improve education and outreach with peers and public

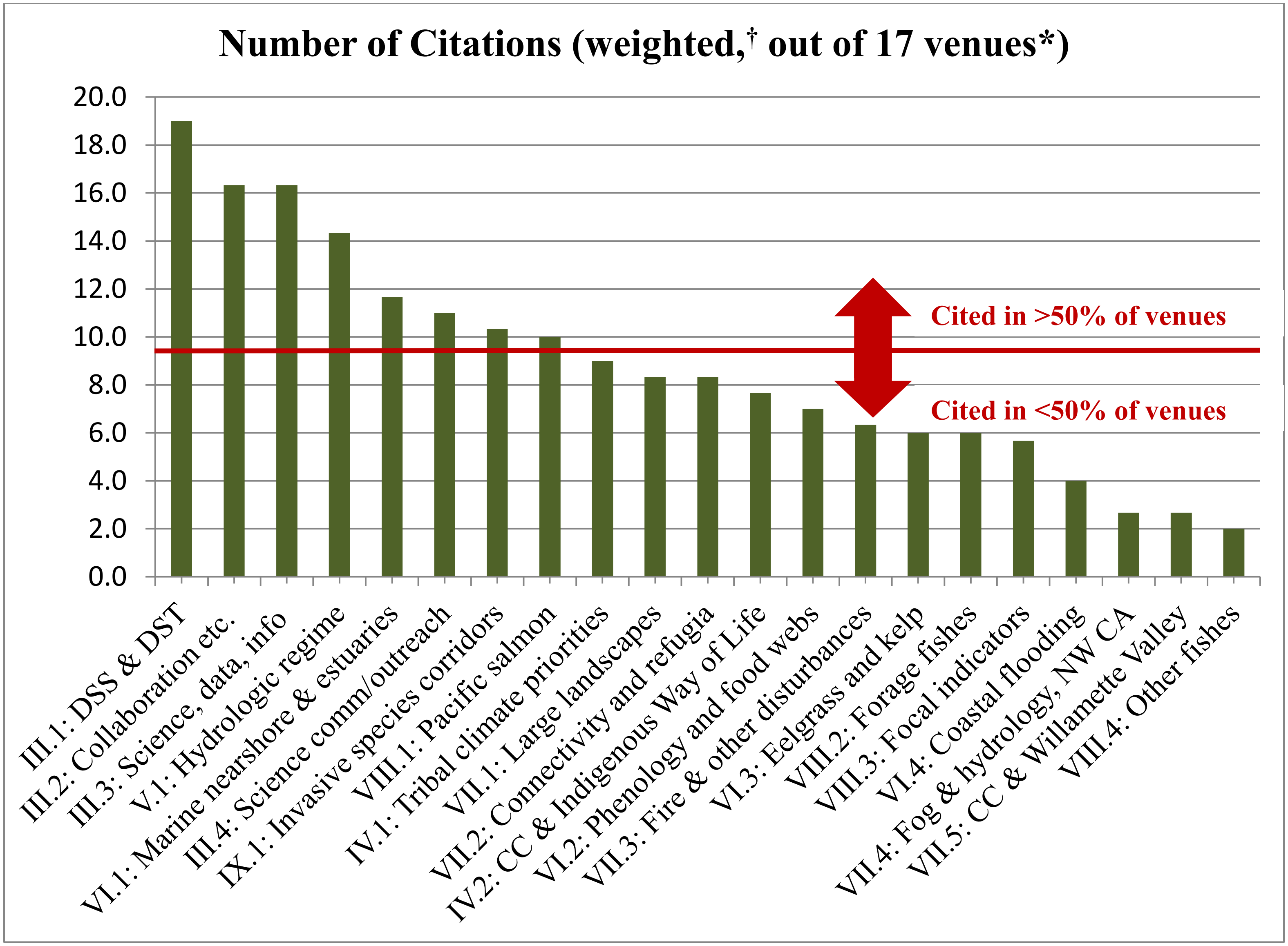

Figure 2. Frequency Analysis of Needs and Activity Areas Identified by Project Participants. *Venues = 1 survey, 13 web-based focus groups, 3 in-person workshops. †There were three web-based focus groups for terrestrial ecosystems, compared to five web-based focus groups each for marine/coastal and freshwater ecosystems. To account for the difference, a weighting factor of 1.67 was applied to each instance in which a terrestrial focus group was cited for a need or activity area (i.e., 1 terrestrial citing*1.67 weight = 1.67 weighted citations). This makes the total number of venues appear to be 19.

III. Core Needs and Opportunities

Project participants identified four types of needs that, if addressed by the NPLCC, would best advance their efforts to address climate change at the landscape scale. These needs were identified frequently across venues or repeatedly within venues. Project participants also identified principles to guide consideration for each of the four needs, which are described in the introduction to each section. The four types of needs are:

1. Decision-support systems and tools
2. Collaboration and other capacity-building activities
3. New or different science, data, or information
4. Science communication and outreach

We use this chapter to introduce these NPLCC-wide needs and to synthesize the key components for each need, as identified by project participants. The remaining chapters, Chapters IV-IX, describe activity areas for particular ecosystems, habitats, species, or indigenous natural and cultural resources. These activity areas are all examples of the four core needs examined in this chapter.

1. Decision-support systems and tools

Every web-based focus group and workshop, as well as several survey respondents, suggested one or more decision support systems or tools to increase capacity and inform climate change-related decision making:

> *Finding tools will be useful. I do not have a feel for what types of potential tools there are. Using things like vulnerability assessments and visualization types of products like maps are very useful… (British Columbia Coast Marine).*[73]

Incidence of Discussion of Need in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	✓
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	✓
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	✓
Columbia River Basin	✓
WA/OR/n. CA Coastal Ranges and Drainages	✓
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	✓
Interior Mountain Ecosystems	✓
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

Decision support for climate change refers to "organized efforts to produce, disseminate, and facilitate the use of data and information in order to improve the quality and efficacy of climate-related decisions" (NRC 2009, p. 2). Descriptions of DSS and DST provided by project participants are consistent with definitions suggested in the available literature (Box 3, p. 20). Project participants most often described decision-support tools (DST) as:

- Models
- Maps
- Vulnerability assessments
- Visualizations of current and potential future conditions

Project participants also identified a number of existing decision-support systems (DSS) that are helpful in their work. These are described briefly in the final section of this chapter.

Project participants described DSS and DST as important tools for addressing some of the challenges associated with managing resources in

[73] This comment was made by a participant in the British Columbia Coast Marine web-based focus group. Throughout the report, web-based focus group input from the transcripts is *italicized* with the focus group identified parenthetically (see Table 6 for a list of the focus groups), but does not include quotation marks because the information was transcribed in a nearly verbatim fashion. Therefore, the transcripts are faithful representations of participant comments, but are not full verbatim quotes. Direct quotes from survey respondents are *italicized* with quotation marks around them.

light of climate change impacts, particularly the lack of tools, capacity, and communication, and the difficulty in incorporating or addressing uncertainty (see Executive Summary for a description of challenges identified by project participants). Under the auspices of the National Research Council, a Panel on Strategies and Methods for Climate-Related Decision Support identified similar challenges (NRC 2009, p. 59-64):

- Resistances to change
- Institutional and legal (structural) barriers
- Organizational and cultural barriers
- Omissions in professional training and education
- Time constraints versus urgency
- Lack of funding and other resources

Strategies to overcome these barriers are described generally throughout this chapter and specifically in Chapters IV.1 (Support the efforts of Tribes, Alaska Natives, and First Nations to identify and address climate-related priorities related to decision-support and capacity-building), V.1 (Increase the resilience of the hydrologic regime to climate change and other stressors), and VII.5 (Support to advance efforts to address climate change in the Willamette Valley, Oregon). These strategies are also consistent with those identified by the National Research Council Panel on Strategies and Methods for Climate-Related Decision Support, which include leadership, mandates, institutional changes and institution building, funding for decision support, and training, education, and exchange of experiences (NRC 2009, p. 64-67).

This section discusses the categories of DST and DSS listed above (models, maps, vulnerability assessments, visualizations of current and potential future conditions), and begins with principles to guide development and use.

Box 3. Decision-support Systems and Tools

Decision-support systems (DSS) are interactive systems that include raw data, models, documents, personal knowledge, and other information to aid individual or group decision-making. NRC (2009) states "they are comprised of the individuals, organizations, communication networks, and supporting institutional structures that provide and use decision support products and services" (p. 37). DSS provide managers and decision makers with access to a dynamic collection of individual tools that may include a library of relevant documents, site-specific data displayed with custom visualizations, and other resources. A decision-support system has three technical requirements: a data- or knowledge-base, a model that reflects the decision context and is guided by user criteria, and a user interface. By contrast, a ***decision-support tool*** (DST) is often tailored to discrete decisions or specific situations and may include scenario evaluations, performance evaluations, or recommendations for specific circumstances. As new decision-support needs arise, DSS support the development of new DST to meet those needs. Examples of DST include ClimateWizard, Habitat Suitability Modeling, and DST for Addressing Invasive Species in Garry Oak and Associated Ecosystems; DSS examples are described in the last section of this chapter.

Sources: Ballard (2012); NRC (2009); Seavy and Howell (2010); Decision Support System. Accessed July 20, 2012 from http://en.wikipedia.org/wiki/Decision_support_system

Principles to guide development and use

Five principles to guide development and use of decision-support tools and systems emerged from the survey, web-based focus groups, and in-person workshops.

Principle 1. Tools and systems should reflect a dynamic, not static, environment

Web-based focus group participants noted that many existing visualization tools to inform climate change adaptation reflect a static or non-dynamic response to projected climate change impacts in the physical and ecological environment (Puget Sound and Georgia Basin Freshwater, Interior Mountain Ecosystems). Dynamic tools would not only better reflect likely responses in the physical and ecological environment, but would be an effective method to foster understanding of climate change impacts and initiate a dialogue with the public and decision makers:

> *Being able to develop numerical or conceptual models that can somehow be animated is often a powerful tool for helping people understand what things are going to look like and then use that to initiate a dialogue. I've seen kind of the opposite going on where I see lots of map output and simulations of sea-level rise but they are done in a static way – water going up but no coastal dynamic response, [they] don't have changes in erosion or deposition of shoreline or estuary (Puget Sound and Georgia Basin Freshwater).*

As noted by the National Research Council (2009), linking information producers and users in a way that respects the differing cultures and incentives of science and practice also enables a "productive and durable relationship…to be built" (p. 40). Further, when connections are built across disciplines and organizations, the "multidisciplinary character of the needed information, the many organizations that share decision arenas, and the wider decision context" are taken into account (NRC 2009, p. 40).

Principle 2. Tools should be selected for or designed with a particular audience and a particular question in mind; systems should be targeted as well, but can be more general than tools

Project participants from four of thirteen web-based focus groups identified the need to target tools to fit particular audiences and questions.[74] For example:

> *Yes we do need a tool to translate the science to guidelines for managers to use. How can or should we tailor this tool to work with different types of managers? (WA/OR/CA Coast Ranges and Drainages Freshwater).*

As one participant from the California Current Marine #1 focus group noted, targeting tools to an audience or location would *help people get from data to decisions.* It would also support long-range planning (California Current Marine #2).

The National Research Council (2009) also identifies designing tools with users" needs in mind as a principle for ensuring decision support processes are effective. They suggest beginning with users" needs, not scientific research priorities and state needs should be "identified collaboratively and iteratively in

[74] The four web-based focus groups represented are Puget Sound and Georgia Basin Marine, California Current #1 and #2, and WA/OR/n. CA Coastal Ranges and Drainages Freshwater.

ongoing two-way communication between knowledge producers and users…[who are the] collections of decision makers who face the same or similar climate-related events or choices and therefore have similar information needs" (p. 40). Two related principles are to structure DSS and DST for flexibility, adaptability and experiential learning, and to begin with the "right process" and balance process with products throughout the development of DSS and DST (NRC 2009, p. 40-41).

Principle 3. Tools should accurately reflect the ecological system in which they are used

Participants noted it is a challenge to get ―*climate science information at the scale and resolution that is useful in making local land use decisions…" (Survey Respondent 29)* and that *it seems like for a lot of these tools it is not useful if you are working on a specific site (California Current Marine #1).* Tools are often designed to be generally applicable in a variety of ecosystems, but the high topographic diversity and event-driven hydrologic regimes in the NPLCC region mean that *we can't take a model from one part of the country and assume that it will work for our area… (California Current Marine #1).*

Principle 4. Tools, specifically models, should include detailed metadata

Metadata improves the credibility of model outputs, research findings, and related products from tools by explaining the origin and context for the data used to generate results. It provides information about when, where, why, and how data was collected, who collected the data, and any caveats or limitations to the data. It should also describe how uncertainty in outcomes is addressed. As an example of the type of metadata to consider for climate change-related models, one web-based focus group participant identified several types of metadata to include with model outputs:

> *Any model output should be accompanied by detailed metadata, including information about habitat classification, model parameterization and model subroutines. For example, did the model use locally or regionally developed submodels for controlling factors such as sediment deposition, organic matter accumulation, and salinity? Are the models spatially accurate? (California Current #1).*

Principle 5. Potential users should be trained in the use of the tool or system

Participants in the California Current #2 focus group and Arcata workshop specifically identified training as a need. For example:

> *…What has been found in Humboldt Bay is that they have not been trained in models and tools so there is a need for demonstrations and trainings for these tools… (California Current Marine #2).*

In their study of decision-support for management and conservation of riparian bird habitat, Seavy and Howell (2010) support the need for training "…our results suggest that simply making these tools available on the web will not be effective. To increase the utility of these tools, ecologists will need to engage with decision makers to provide the training they need to effectively use the tools" (p. 1265). Further, to enhance the return on investment for training and "obtain greater visibility, stature, longevity, and effectiveness" for DSS and DST, seeking institutional stability, either formally or through less formal networks, has been suggested as a principle of effective decision support (NRC 2009, p. 41).

Basic visualization models and maps

Project participants from six of thirteen web-based focus groups,[75] the Juneau workshop, and the survey identified visualization tools such as models and maps as a tangible and useful method for communicating information and identifying high-priority areas for conservation on the landscape:

> *…one of our challenges is trying to communicate this information to other people who may not be science-based. Maps say so much more than reports and data tables and Excel spreadsheets… (Coastal Temperate Rainforest Ecosystem).*

> *…when I hear the word tools from people – they're usually asking for some type of mapping or online interactive sort of thing that they can sit down and work through the data themselves… (Columbia River Basin Freshwater).*

> *…I think that visualization tools are the way that most of us understand things the best. Under what scenarios, where will the water be and how can we prioritize? Where can wetlands migrate…? (California Current Marine #2).*

> *[I] have found effective vulnerability maps. People really like those for prioritization so that you can see that some areas will not be impacted… (Puget Sound and Georgia Basin Marine).*

These types of tools should be geospatially based and supported by a geospatial data platform in order to identify vulnerable habitats or landscapes (Juneau workshop). Some participants stated there is a ―*lack of tools [to] help us identify high priority areas for conservation in the Pacific Northwest" (Survey Respondent 39),* while others indicated there is sufficient data and information to move forward, and tools should be used to build on that information:

> *―I think the information/tools/research is there – just need to be constantly looking at what the scientific community is learning. Having user friendly web sites that have models of sea level and temperature change scenarios would be great" (Survey Respondent 15).*

> *―We need to build on what we are already doing for species and habitats, we don't need to re-invent the wheel here… no more planning guidances…just some good tools to help us identify priority areas and on the ground management plan recommendations" (Survey Respondent 19).*

[75] The six web-based focus groups represented are Puget Sound and Georgia Basin Marine, California Current #1 and #2, Pacific Coast and Nass Ranges Freshwater, Coastal Temperate Rainforest Ecosystem, and Interior Mountain Ecosystems.

Vulnerability assessments

Throughout the NPLCC region, many project participants are just beginning to take action to address climate change in their work. Particularly in Alaska, vulnerability assessments (Box 4) are identified as among the first steps to take to identify potential priority areas and adaptation actions:

> *We need to know the range of vulnerability such as how and where shifts are likely to occur. Which systems are more and less productive? What changes and transitions are likely to occur? We should use this as a starting point and should use logic to figure this out (Alaska and British Columbia Coastal Freshwater Ecosystems).*

Survey respondents suggested species distribution and vulnerability assessments for wildlife and other species are needed (Survey Respondents 36 and 71), while web-based focus groups participants identified some specific locations where vulnerability assessments are needed or ongoing:[76]

> **Box 4. Defining Vulnerability and Vulnerability Assessment**
>
> ***Vulnerability*** is defined as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2007, p. 883).
>
> A ***vulnerability assessment*** is "a key tool for carrying out adaptation planning, and informing the development and implementation of climate-smart resource management practices" (Glick et al. 2011, p. 137).

- Willamette Valley, Oregon: ―*We are working with the CIG on a vulnerability study of systems and select species to the anticipated effects of climate change in the Willamette Valley…" (Survey Respondent 71).*
- Pacific Northwest: The University of Washington and partners are assessing the sensitivities of species and ecosystems to climate change in the Pacific Northwest. Results are available in an online database.
- Southcentral Alaska: ―*A climate vulnerability assessment is currently underway in the southcentral Alaska area. This assessment includes downscaled climate projections by the Scenario's Network for Alaska Planning (SNAP) and university and interagency teams reporting on the following topics: salmon, biome-shifts, cultural resources, snow & ice, and coastal resources" (Survey Respondent 70).*
- Southeast Alaska: Participants in southeast Alaska requested a southeast Alaska vulnerability assessment that is *connected across the Gulf [to southcentral Alaska] and to the British Columbia Coast (Southcentral and Southeast Alaska Marine).*[77]

[76] Three web-based focus groups discussed vulnerability assessments: Southcentral and Southeast Alaska Marine, Alaska and British Columbia Coastal Freshwater, and Interior Mountain Ecosystems. Juneau and Arcata workshop participants also discussed vulnerability assessments.
[77] Participants from the Alaska and British Columbia Coastal Freshwater focus group also made this request.

A better understanding of the vulnerability of species and ecosystems given climate change was often discussed in tandem with prioritizing these vulnerable species and places for adaptation:

> *… Specifically, I would reiterate conducting vulnerability assessments is a key need… Maybe identifying targets for conservation or risk assessments – we may need some help on that… (Interior Mountain Ecosystems).*

Finally, project participants stated that the results of a vulnerability assessment were not only helpful for early prioritization efforts and to *defend our work (Interior Mountain Ecosystems)*, but are a prerequisite for determining the intensity of needed conservation activities and adaptation actions:

> *…[the vulnerability assessment] has to be done but the real product is adaptation actions…that is the really critical piece for us – what kind of management actions can we do to minimize vulnerability of these resources or species that come out as highly vulnerable through the assessment… (Interior Mountain Ecosystems).*

> To overcome the challenges associated with incorporating climate change into work, *―mov[e] beyond vulnerability predictions to more geospatial [approaches] to assist with target areas and magnitude of impacts of climate change… what [are] the magnitude of conservation activities that will be needed"? (Survey Respondent 67).*

The former example suggests vulnerability assessments may be informative as tangible examples of progress or success and provide a critical link to actionable information and solutions (see Chapter III.2, p. 28), while the latter example indicates vulnerability assessments may inform spatial decision-support systems and tools (discussed in the next section). In addition to informing the intensity of needed conservation activities and adaptation actions, vulnerability assessments can also inform the timing of adaptation actions because sensitivity, exposure, and adaptive capacity vary in time as well as space (Smit and Wandel, 2006). Training to conduct vulnerability assessments is currently available, for example through the National Conservation Training Center or by modifying the Planning for Climate Change Workshop approach.

Examples of decision-support systems

Project participants from the Puget Sound and Georgia Basin Marine web-based focus group, all three terrestrial ecosystem web-based focus groups, and the Arcata workshop identified several examples of existing decision-support systems, as well as requests for new decision-support systems.

Requests for new decision-support systems included a prioritization tool for tradeoffs among short- and long-term effects and benefits and a user-driven, expert-assisted web interface to ask climate-related questions about a landscape:

> *…It would be helpful to have any sort of tools that can help us strengthen those analyses…And then maybe prioritization tools for tradeoffs of… short-term effects vs. long-term benefits. How would you look at the landscape to maintain and address both long- and short-term needs? (Interior Mountain Ecosystems).*

…So one thing I would like to do from within OCCRI is to develop an off-the-shelf suite of products where someone could come to us, not automated, but a user-driven process where there is a web tool and they could map out a domain and look at the different projections that the various modeling efforts in terms of the climate parameters they are interested in… there is also an interpretation step that we would be reluctant to skip…I would like to be able to provide people with more definitive answers to their questions… (Lowlands, Prairies, and Other Non-forested Systems).

In keeping with this chapter"s focus on providing general information and directing the reader to the following chapters for ecosystem-specific information, a short summary of each existing decision-support system identified by project participants is provided the below. If project participants discussed the decision-support system in light of a particular ecosystem, the chapter and section where more information is available is also provided:

- **Sea Level Affecting Marshes Model** (SLAMM): SLAMM "simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise." It was developed by Warren Pinnacle Consulting, Inc. and has been used by U.S. federal agencies (e.g., USFWS, NOAA, USEPA, USGS), NGOs (e.g., National Wildlife Federation), and researchers. Within later versions of SLAMM (5.0, 6.0, 6.0.1 Beta), five primary processes can affect wetland fate under different scenarios of sea-level rise: inundation, erosion, overwash, saturation, and salinity. Additional information on SLAMM is available in Chapter VI.1 (p. 89).
- **Ecosystem Management Decision Support** (EMDS): EMDS is "an application framework for knowledge-based decision support of ecological assessments at any geographic scale" originally developed by the U.S. Forest Service. It is currently maintained by the Redlands Institute of the University of Redlands. EMDS addresses a range of management-relevant questions including "what can we conclude from our data about the state of the landscape" and "how much influence do missing data have on obtaining a logically complete analysis."
- **Vegetative Diversity Dynamics Tool** (VDDT): VDDT is a "state and transition landscape modeling framework for examining the role of various disturbance agents and management actions in vegetation change." It was developed by ESSA Technologies and has been used by The Nature Conservancy and LANDFIRE. VDDT provides information about the potential sensitivity of the ecosystem by projecting changes in vegetation composition and structure given inputs about various processes and disturbance agents (e.g., fire, insects, pathogens, weather, species competition).
- **Climate Resilience Evaluation and Awareness Tool** (CREAT)**:** CREAT is "a software tool to assist drinking water and wastewater utility owners and operators in understanding potential climate change threats and in assessing the related risks at their individual utilities" developed by the U.S. EPA. CREAT provides libraries of information for water and wastewater utility assets, possible threats due to climate change, and a range of adaptation measures that could be taken. It also guides users through a process to identify and incorporate regional differences in the assessment. Finally, CREAT "provides a series of risk reduction and cost reports that will allow the user to evaluate various adaptation options as part of long-term planning."
- **Skeena River Adaptation Toolkit:** The Toolkit is "intended to help those living in the communities of the lower Skeena to adapt to the changes associated with Climate Change." The

toolkit uses an interactive, web-based interface that combines a visual slide show with narration and text. It provides an overview of climate adaptation, valued community and environmental resources, climate change effects in the Skeena watershed and key habitat types, and possible adaptation actions. The toolkit avoids technical language, but includes links to technical information for those who are interested.

- **Envision:** Envision is "a GIS-based tool for scenario-based community and regional planning and environmental assessments" developed by Oregon State University. It is currently being used in the Willamette Water 2100 project. Envision combines a spatially explicit representation of the landscape with decision rules "that are grouped into alternative scenarios, landscape change models, and models of ecological , social and economic services to simulate land use change and provide decision-makers, planners, and the public with information about resulting effects on indices of valued products of the landscape."
- **NOAA Coastal Services Center Digital Coast:** NOAA CSC Digital Coast provides tools, training, and other information to make data usable for coastal management. It includes, for example, a coastal inundation toolkit, a sea-level rise and coastal flooding impacts viewer, a primer to incorporate sea-level change scenarios at the local scale, guidance for addressing social impacts, and "spatial techniques and resources to prioritize wetland conservation."
- **Climate IMPACT Decision Support Tool** (CIMPACT-DST): CIMPACT-DST is a "first-of-its-kind integrated platform for climate adaptation planning…It combines the latest climate change science and best-practice adaptation strategies with your organization‟s policies and guidelines to provide consistent recommendations to planners, project managers, and other departmental staff throughout the organization." It was developed by Cascadia Consulting, Inc. Contact Spencer Reeder at spencer@cascadiaconsulting.com for additional information.
- **NatureServe Vista:** NatureServe Vista is a flexible and free decision-support system that "helps users integrate conservation with land use and resource planning of all types" including land use, natural resource management, and ecosystem-based management. NatureServe Vista incorporates science, expert opinion, community values, and GIS and allows the user to "evaluate, create, implement, and monitor land use and resource management scenarios designed to achieve conservation goals within existing economic, social, and political contexts."
- **Madrona:** Madrona is "a software framework for effective place-based decision making." It uses a spatial and visual web application "built on libraries such as Django, PostGIS, JQuery, OpenLayers and Google Earth." Users can develop and compare management scenarios, including tradeoffs among management options, based on the pre-determined objectives and values of planners and stakeholders. A range of technology services, training, and other support are available to assist the user, including step-by-step tutorials and case studies in which Madrona has been applied.

2. Collaboration and other capacity-building activities

Participants from eleven of thirteen web-based focus groups, all three workshops, and many survey respondents discussed the need for capacity-building and assistance with collaboration throughout the NPLCC region. "Capacity" refers to the ability of people as well as financial, technical, political, and institutional systems to set and accomplish goals and objectives. This includes, for example, the training to address and incorporate uncertainty:

> *…I think we need to do better teaching people about vulnerability and building resilience and inventorying the things that are important to you as resource managers and thinking about climate and how to adapt if the climate changes, but maybe not knowing specifically what the climate change will be (Columbia River Basin Freshwater).*

Incidence of Discussion of Need in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	✓
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	✓
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	
Columbia River Basin	✓
WA/OR/n. CA Coastal Ranges and Drainages	✓
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	✓
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

Project participants identified five principles to guide capacity-building and collaboration:

- Emphasize integration and leveraging of existing resources, as opposed to generation of new resources.
- Target capacity-building and collaboration efforts to particular audiences and particular questions.
- Provide the capacity and support for collaboration that moves partners and stakeholders toward action or further enables action on the ground.
- Make use of conceptual models and include coordination and organization of NPLCC landscape-level goals and measurable objectives in a hierarchical framework that focuses on general needs and feeds down to more specific needs, both for the ecosystem and for non-ecosystem needs (Arcata workshop).
- Provide a *synthesis or conceptualization of what the management needs are* across the landscape in a way that *respects the tools that are available and the mandates available to each agency (Coastal Temperate Rainforest Ecosystem).*

These principles respond to three commonly cited capacity constraints while also reflecting the unique position of the NPLCC in the institutional landscape. The three commonly cited constraints are:

- Lack of time
- Overwhelming amount of information
- Lack of funding to pursue desired goals and objectives

For example, there is *no time to stay abreast of current literature (WA/OR/CA Coast Ranges and Drainages Freshwater)* and, as one focus group participant noted, *I struggle with the amount of info that is out there and my ability to absorb it (Puget Sound and Georgia Basin Marine).*

In addition, there is a lack of institutional knowledge of the available tools and limited capacity to acquire additional institutional knowledge given limited funding and overburdened staff:[78]

> *―Who has time to go out and find the latest tools, research, and other resources that may be available with all of the other tasks I need to work on?...‖ (Survey Respondent 10).*

In response to these constraints, some participants stated they ―*primarily need more staff time and resources to incorporate existing tools, data and resources in decision-making processes‖ (Survey Respondent 29),* but most identified the need for additional information and management tools, both to make existing work easier and to facilitate incorporation of climate change into their work. Three primary topics for capacity-building and collaboration were identified through the surveys, web-based focus groups, and in-person workshops:

- Guidance and tangible examples of progress or success in addressing climate change
- Synthesis products
- Facilitated coordination, collaboration, and leveraging among people, projects, institutions, and funding

Guidance and tangible examples of addressing climate change

Project participants from throughout the NPLCC region identified the need to move from understanding impacts to taking action on climate change:

> *I am at the point where I want to see the community of practitioners dive in and act on these proposals. I would love to really see what is happening across the landscape in terms of seriously implementing the design in climate change (California Current #2).*

Six of the thirteen web-based focus groups discussed the need for guidance and examples of progress or success with climate change adaptation,[79] as well as those participating in the Arcata workshop and those who took the survey. Suggestions fall into two broad categories: guidance such as best management practices or how to incorporate climate change into existing practice, and tangible examples of progress or success such as case studies.

[78] This constraint was also identified in the California Current Ecosystem #2 web-based focus group.
[79] Web-based focus groups represented are British Columbia Coast Marine, California Current Marine #1 and #2, Pacific Coast and Nass Ranges Freshwater, Columbia River Basin Freshwater, and WA/OR/n. CA Coastal Ranges and Drainages Freshwater.

Guidance

Guidance documents would reduce barriers to incorporate climate change into existing policies, programs, and plans. Project participants suggested a range of guidance documents:

- Documents to assess the pros and cons of controversial research applicable to management decisions (British Columbia Coast Marine, Pacific Coast and Nass Ranges Freshwater)
- Practical "Best Management Practices" manuals or guidelines that outline how to incorporate climate change considerations into municipal plans, mitigation plans, enhancement and compensation plans (British Columbia Coast Marine, Pacific Coast and Nass Ranges Freshwater)
- The California Coastal Commission suggests policy research to produce "*…examples of policies and ordinances that implement measures to avoid and mitigate impacts of climate change [that] can provide guidance for local governments" (Survey Respondent 33, also see p. 6 of California Coastal Commission, 2008).*

Project participants also requested assistance to identify:

- The conditions in which existing regulations would support future resilience to climate change
- Climate-sensitive habitats and priorities that current authorities could address (California Current Marine #2).

For example, ―*…a primer on climate change policy issues relative to regulatory programs would keep us from reinventing…" (Survey Respondent 57).*

Tangible examples of progress or success

Case studies and similar examples of progress or success would build further capacity by providing a learning mechanism and resource for managers, conservation practitioners, and others:

> *People really appreciate how people are addressing climate change. There is a need for case studies, as detailed, practical and specific as possible (WA/OR/n. CA Coast Ranges and Drainages Freshwater).*

> *… We don't really know how successful these [hydrology and adaptation techniques] were so if you could look at where good things have come out it would be very beneficial (Pacific Coast and Nass Ranges Freshwater).*

> *…We do need to look at some of these decisions we're making on adaptation and say: ―this is where it works, this is where it does not work." And since it is a fairly new way of thinking, it's tough… (Columbia River Basin Freshwater).*

Examples of progress and success also demonstrate how existing approaches to address non-climate stressors could play a role in current and future climate change adaptation:

> *The Gitanyow have a comprehensive land use plan for their traditional territory now…Because we had this land use plan in place, we had a much stronger argument to get BC Hydro to pick an alternate route for the [Northwest transmission] line and so they*

did… I see comprehensive land use plans as an important way to adapt (Pacific Coast and Nass Ranges Freshwater).

Despite early examples of progress and success, project participants acknowledged that "proof" for case studies may be several years away given the time needed for systems to respond to management and/or adaptation actions:

One of the challenges we're faced with is how to show the benefit of [an action], for example the benefit of riparian restoration or taking down barriers to fish. What we find is there is a real delay in some of the metrics because you can restore a riparian area, but it takes 20 years for the trees to grow. So you can start to measure some of those benefits, but there's a longer delay to actually show benefits to other species like fish because you have so many other variables like ocean conditions and long lifecycles. It can be a real long-term project to actually show success and the benefit of those actions (Columbia River Basin Freshwater).

Although "success" may take many years to manifest, several specific case studies were suggested:

- —*…sucessful pilot studies…" (Survey Respondent 57).*
- *We should probably focus on success stories and make them more available, e.g. hydrology, adaptation technique… (Pacific Coast and Nass Ranges Freshwater).*
- Case studies of thinning treatments that prevented a stand-replacing crown-fire to inform current and future forest management in northwest California, promoting healthy forest growth for increased carbon sequestration, stabilization of sediment that prevents accelerated erosion, and land purchase or protection for carbon sequestration and resiliency (Arcata workshop).

Actionable information and solutions

Several project participants went a step beyond asking for guidance and tangible examples of progress (see previous section) and specifically requested information, tools, and data at the level and scope that would enable climate adaptation and preparedness actions to be taken:

It would be helpful to have research done (or results disseminated) that answer specific natural resource management/conservation questions and leads to the ability to plan and implement on-the-ground actions… (Survey Respondent 53).

This request was often made in tandem with the request for solutions that could be implemented immediately and would respond directly to challenges participants face:

Our largest challenge is to identify actions that we can take that will be beneficial to our member tribes, and which are not already being performed at the regional level (Survey Respondent 48).

There is a lack of specific tools and associated regulatory frameworks (and political will) for local and regional decision makers to use to take action (Survey Respondent 8).

The biggest challenge remains the need for actionable level information and analyses, particularly best available downscaling and scenario planning that works for landowners/managers, communities, and conservation agencies (Survey Respondent 78).

Actionable information enables decision makers to take action at their "individual level of authority or influence" (NOAA, 2011, p. 17). Actionable information and solutions includes specific changes to existing policies and programs such as increased buffer zones and on-the-ground management actions:

…what kind of management actions can we do to minimize vulnerability of these resources or species that come out as highly vulnerable through the assessment…? (Interior Mountain Ecosystems).

In regards to specific actions, I think protecting headwater streams is where I would put my priority because that is a big gap in our policy, and it is part of one of the more sensitive aspects of our hydrologic system (Pacific Coast and Nass Ranges Freshwater).

We should have larger buffer zones on small streams and plant trees for shading to at least reduce temporarily the effect of water warming… (Pacific Coast and Nass Ranges Freshwater).

Synthesis products

All web-based focus groups on marine ecosystems, all three workshops, several survey respondents, and participants in the Columbia River Basin Freshwater and Coastal Temperate Rainforest Ecosystem web-based focus group discussed synthesis products. Synthesis products refer to efforts to compile, organize, and synthesize the available information on a particular topic, geography, group of people, or other category of information in a single location such as a report, website, or database. Overall, participants suggested three categories of synthesis products to facilitate research and management collaboration or to build technical and institutional capacity:

- Integrated, consistent, seamless datasets
- A "climate clearinghouse" for contact information, scientific literature on climate change, and/or an inventory of existing research
- An assessment of when, where, and under what conditions to use tools

An additional suggestion from the Columbia River Basin Freshwater web-based focus group is to compare and contrast approaches and methods for climate change adaptation:

What we've talked about here is adaptation studies and looking at the methodologies people have employed. If you guys could do that, that would be phenomenal…I think it would be very useful because so many people are starting to think about these things and have taken different approaches, but there's not a one-size-fits-all approach to adaptation and one's not better than the other, but it's interesting to think about these things and whether they could apply to a certain community or a certain sector (Columbia River Basin Freshwater).

Synthesis Product 1. Integrated, consistent, seamless datasets

To produce integrated, consistent, and seamless datasets and reduce cross-boundary barriers to collaboration, project participants suggested beginning by identifying and organizing key base data layers, then organizing the datasets into a single location that is accessible by all. NOAA (2011) observed that "establishing standards, methods, and protocols for data collection, storage, and analysis…provides a platform for others to build upon what is already known and „better integrate science into decision-making‟" (p. 16). Since ―*lots of people are serving up data,"* project participants emphasized the role for the NPLCC is to organize and integrate – there is ―*no need to reinvent the wheel"* (California Current Marine #2, Arcata workshop).

Efforts to identify key base data layers should focus on those that are used by many or most scientists in the region, should include an explicit identification of data gaps, and should provide a mechanism to acquire data (Arcata workshop). In addition to these guidelines, Arcata and Juneau workshop participants suggested development of criteria for the "best data" and an emphasis on baseline information that is as current and relevant as possible. Juneau workshop participants suggested a common portrayal of environmental data layers in GIS format, which could be achieved by encouraging similar standards and formats in data collection. In response to a question about additional tools for the NPLCC region, one survey respondent noted a multi-agency approach is needed if integration efforts are to be useful across the region:

> *We need ―a stronger multi-agency federal hand in guiding and, more importantly, establishing criteria against which regionally downscaled data can be assessed. Ideally, there would be federally sanctioned regional data sets of the core climate projection data (temp & precip) at a high enough temporal and spatial resolution that would serve the largest possible range of users and would short-circuit the uncontrolled mad dash for everyone to create their own downscaled data sets. This will only be of use if this effort is multi-agency (NOAA, DOI, others)" (Survey Respondent 26).*

As the priority datasets and datalayers are identified, the NPLCC could serve as a "node" or "shared data warehouse" in the larger community of data portals (Portland workshop, Arcata workshop). Shared ownership and full access for all NPLCC members and stakeholders was suggested as a feature of the data warehouse (Portland workshop). The data warehouse should be searchable and could include existing databases, maps, or GIS by other entities (Arcata workshop). Portland workshop participants noted that many specific ideas have been discussed by the Alaska Coastal Rainforest Center‟s Data Integration Workshops and are available on their website: http://acrc.alaska.edu/acrc_sw/workshops/index.html (accessed 4.2.2012). For a discussion of the pros and cons to developing new portals or modifying existing portals, see the next sub-section, which is entitled ―*Climate Clearinghouse."*

Integrated, consistent, and seamless datasets across the NPLCC region would enable a range of analyses and research that are currently difficult to accomplish. For example, to separate real cause and effects from random co-occurrences and help communicate and analyze data, Portland workshop participants identified multi-variate analyses and consistent data sets as a need in the NPLCC region. As patterns emerge, finer analyses can be conducted, though the data should be usable at the local scale from the beginning. While multi-variate analyses are needed immediately, additional planning is needed to coordinate and develop consistent data sets. Partners in these efforts include food web modelers, land use planners, Army Corps of Engineers General Investigations, BC Marine Conservation Analysis (BCMCA), graduate students, and federal and state agencies. BCMCA, for example, is developing a shared dataset for coastal managers.

Synthesis Product 2. Climate clearinghouse

All three in-person workshops, survey respondents, and seven of ten web-based focus group calls included a rich discussion of the pros and cons to the NPLCC producing some type of portal to connect people with projects, people with scientific literature, or people with other people. Some participants felt the region was already in a "portal proliferation" phase, and suggested either 1) making use of existing portals, or 2) finding new ways to help people access and use information:

> *I think portals can be really useful. Sometimes they are better targeted if they follow a face to face workshop… with the people that you want to have involved in it…Then you have a group of people who have bought into it so that they can help pass it on to people in their area (Southcentral and Southeast Alaska Marine).*

> *In terms of accessing information through a clearing house, I think it will be really useful but it will also require an interaction with the experts…Caution in having one large clearing house. At some level there will have to be some interaction and tailoring to your question… (Puget Sound and Georgia Basin Marine).*

Other participants, for example the web-based focus group participants above, noted that the reason portals proliferate is because they are ultimately designed to fit a particular purpose. Participants suggested the NPLCC could identify and assess existing portals to determine what is available, what may be missing, and what may be most useful in the NPLCC region (California Current Marine #1, Puget Sound and Georgia Basin Marine). On that note, participants had various ideas about the type of portal that would be most useful, but overall, participants seemed to prefer a simple portal providing contact information and a brief description of expertise for those working in the region:

> *Need to be aware of who's working where and on what – just brief – to know how to get in touch. Don't need reports, etc. just need contact information (California Current Marine #1).*

Secondarily, a portal with brief descriptions of projects or literature was requested:

> *… we need to be aware of who is doing work in what areas. We just need a list and a brief project description. Don't need data management or full data but just links to contact information for people to get in touch with others. [There is existing work by a colleague, who] is in communication with folks to do that (California Current Marine #1).*

> *Provide a review of the projects that are doing this work so that those of us who need examples have them… (California Current Marine #2).*

Develop an easy-to-use clearinghouse of information on climate change for species and effects (U.S. Forest Service has a database for fire effects). It should be national in scope but drilled down to a more regional level (Arcata workshop).

Some participants supported a "question and answer" feature to the clearinghouse, similar to online fora such as ask.com (Puget Sound and Georgia Basin Marine). Building on this idea, several participants suggested a reference librarian for the NPLCC region:

A reference librarian or ―ynta" service would be helpful. Avoid portal overload, don't reinvent the wheel, but use existing portals and services. Someone to call for guidance (California Current Marine #1).

I would like to argue for not just a clearing house but for a library service. Avoiding portal proliferation syndrome...The librarian makes it so that people can call and not have to wade through everything themselves (California Current Marine #1).

Coastal decision makers from throughout the United States also requested a similar centralized database and resource list with information "housed in a single location for easier access and better understanding of what else may be available," including a way for users to share information that may be of interest to others (NOAA, 2011, p. 16).[80]

Finally, Portland workshop participants outlined development of a web-based portal for the NPLCC that would utilize "personal brain software." This software allows the user to query the system and organize information based on their needs. It is a fluid system loosely organized around identified problems. Its structure is similar to a community portal. Participants suggested inviting university students to assist with the initial start-up effort, including integrating data in the portal and assisting with web development.

Synthesis Product 3. Assessment of when, where, and under what conditions to use tools

While the need for additional tools was cited consistently by project participants (see Section 1 in this chapter, Decision-support systems and tools), the need to know which tools to use where, when, and for what purpose was also cited frequently:

What we realized last year when you start looking at adaptation strategies or planning, there are so many tools it is hard to say what is the most useful. There is no summary on what might be most useful… they [the NPLCC] could lead in identifying which tools could be used for what for lay managers as much as anything. Which tools work and are helpful for the region, identify which tools could be used for particular managers in particular locations and regions (Southcentral and Southeast Alaska Marine).

[80] Coastal decision makers are defined as those "who have significant influence in the coastal communities that they manage and where they work. They make decisions about the management and use of land and resources that are likely to be affected by sea-level changes" (NOAA 2011, p. 6). They include tribal, state, and local planners; coastal managers; regional and local professional organizations; port authorities and operators; federal and state natural resource and habitat conservation, restoration, and protection managers; and, practitioners and land-acquisition partners (NOAA 2011, p. 6).

…thinking about the tribes that I work with, having much more specific information about where data is available for the various regions throughout the NPLCC [would be useful] because they are varied in the coastal areas – what do tools and datasets provide for each region? (California Current Marine #2)

This includes information on the advantages and disadvantages of using a particular tool and the quality of data used to derive results:

There is a major need to compare different tools to see what their advantages and disadvantages are. I also want to point out that the data input and the parameterization of input makes such a huge difference in the outcome… California Current Marine #1).

In regards to reliance on tools, aren't some better than others in helping you inform your decision? It depends on the data input and it is hard to understand which tools help instead of hinder you based on the quality of data and the effectiveness of the question that you are asking. Have to know which ones to use and how well they work… (California Current Marine #2).

Quality Assurance (scale or accuracy) is certainly a concern – need to know how good a tool is, the quality of data (California Current Marine #2).

Information on the ideal location and regional applicability of a tool was also requested:

Finding tools will be useful. I do not have a feel for what types of potential tools there are…I will be interested to see how easy it is to take the tools for BC that you have and put it in for California (British Columbia Coast Marine).

They [the NPLCC] could provide guidance on resources organized around particular issues (i.e., regional differences among tools, organized by issues). And then they could do some regional components of that because there is a large latitude range… (California Current Marine #2)

As a resource for comparing tools, project participants suggested NOAA"s Digital Coast *Sea Level Rise and Coastal Flooding Impacts Viewer*, specifically a comparison guide produced by NOAA and The Nature Conservancy entitled Marshes on the Move: A Manager"s Guide to Understanding and Using Model Results Depicting Potential Impacts of Sea Level Rise on Coastal Wetlands (PDF, 1.10 MB).

Facilitated coordination, collaboration, and leveraging among people, projects, institutions, and funding sources

Project participants from eight of thirteen web-based focus groups,[81] all three workshops, and several survey respondents requested support to overcome institutional and international barriers to coordination and collaboration both within standard "boundaries" (e.g., states, agencies) and across those boundaries. Participants routinely described the NPLCC as a "hub" for the collection, synthesis, and dissemination of information and suggested the NPLCC serve as a coordination network to facilitate the exchange of people, data, technology and information.[82] The NPLCC may be well-suited to the task:

> *To the extent that the NPLCC can facilitate people with meager resources to leverage their information to try and get at a much larger problem that might be one of the most feasible options at this point…(California Current Marine #1).*

Requests for the NPLCC to facilitate coordination and collaboration to address political and institutional barriers focus in three broad areas: people, institutions, and funding sources. These requests are consistent with NOAA‟s observation that interdisciplinary and integrated decision making is a broad, thematic need for addressing climate change effects (NOAA, 2011, p. 15-16). Following a discussion of the primary source of political and institutional barriers in the NPLCC region, each of the three areas is discussed in turn.

Key sources of political and institutional barriers to climate change work

Web-based focus group participants across the NPLCC distinguished among the primary source of political and institutional barriers. In British Columbia especially, as well as the Strait of Juan de Fuca (both the U.S. and Canadian lands), the federal and provincial or state government was cited as the primary impediment to climate change work:

> *…most of the work will not be done by federal and government agencies but will have to be done between communities (British Columbia Coast Marine).*
>
> *There is currently a move to work not at the federal level but at the local; community and municipality level. What are some actions locals can take even if they don‗t have the funding for change? What can they do? We need directions for local and regional work (British Columbia Coast Marine).*
>
> *Provincial and federal cuts for staff – our resource approval staff and regulatory and enforcement staff….and the government does not seem to be putting the environment as a priority (Puget Sound and Georgia Basin Marine).*

[81] The web-based focus groups represented are Southcentral and Southeast Alaska Marine, Puget Sound and Georgia Basin Marine, California Current Marine #1 and #2, Alaska and British Columbia Coastal Freshwater, Pacific Coast and Nass Ranges Freshwater, and Coastal Temperate Rainforest Ecosystems.
[82] This observation was made in all the web-based focus groups identified in the previous footnote, as well as all three workshops and by several survey respondents.

In the U.S. in general, a resistance to addressing climate change on the part of government decision makers was cited relatively infrequently by web-based focus group participants. In fact, U.S. federal resource managers and decision makers were well-represented during the web-based focus groups and were actively considering how to incorporate climate change into their work:

> *The largest question from program staff is how to incorporate climate change into my work. First step is awareness…Then we are finding that each program is different so we are looking for what are the commonalities (Puget Sound and Georgia Basin Marine).*

The primary source of political and institutional challenges cited by U.S. web-based focus group participants (with the exception of the Strait of Juan de Fuca) was at the municipal or state level, either due to a lack of belief in climate change or funding and related capacity issues:

> *The comment I get a lot is that there is no time or resources so how can you incorporate sea level rise? They are including a wide array of ways to look at sea level rise adaptation through the lens of established programs (Puget Sound and Georgia Basin Marine).*

> *Trying to figure out how to incorporate climate change data into practical regulatory requirements is challenging…If our permit processers could have information at their fingertips…We have a general idea of Oregon coast and inland as to which watersheds are going to be changing from snow to rain dominant. I am not really sure how to incorporate the information (California Current Marine #1).*

> *I just want to echo that point: in terms of [the California] Coastal Commission and incorporating climate change into coastal program process, capacity and information seem to be main barriers. One problem is that most of the regulation is transferred to local governments that were done in the 80's and most don't look at future rates because when they were done they were not talking about sea level rise (California Current Marine #1).*

Facilitate coordination, collaboration, and leveraging among people

Project participants identified four primary ways the NPLCC could facilitate coordination, collaboration, and leveraging among people:

- Coordinate and collaborate across disciplines to facilitate learning and leveraging opportunities.
- Coordinate along the decision spectrum, from data collectors to data users and finally, to decision makers. This would improve the use of scientific and technical information in decision making.
- Convene regular in-person meetings, workshops, or science symposia to enable managers, scientists, and others from diverse disciplines to work on climate change issues face to face.
- Streamline communications and requests for information to reduce the number of times stakeholders are contacted with similar information requests or invitations. This would improve the effectiveness of communications efforts.

These requests are consistent with NOAA‟s observation that decision makers‟ requests for "data, tools, and services are punctuated with their clear need for the information to integrate biological, physical, ecological, economic, and social information" because "decision makers understand they are facing increasingly complex issues that required multifaceted solutions" (NOAA, 2011, p. 16).

Project participants work in a range of disciplines and perform a number of roles across the NPLCC region. These include sustainable resource management, conservation, climate change adaptation, and related research at the nexus of climate change and ecosystem response. Project participants also work in a variety of institutions, such as federal, tribal, and state agencies, universities, and nongovernmental organizations. As one web-based focus group participant noted, the diversity of roles and institutions generates a need for assistance with coordination and collaboration across disciplines:

> *One thing that comes to mind that you could help with is that a lot of us come from different disciplines. We don't keep up with everyone else and it would be great to be kept in the loop about what else is going on out there. A lot of scientists work in their own disciplines but we could certainly benefit on coordination, and finding out and tapping into what others are doing (Southcentral and Southeast Alaska Marine).*

Coordination and collaboration across disciplines also includes assistance identifying the expertise that is compelling to decision makers. For example, those working in British Columbia noted that collaborating with engineers, who were from a peer group similar to the local government decision makers, made a *real difference* because *they have more credibility than a stewardship group (British Columbia Coast Marine).*

There is also a need to coordinate along the decision spectrum, from data collectors to data users and finally, to decision makers (Arcata workshop). This type of coordination would allow decision makers to request tools and information from data users, who can request it from those collecting the data (Arcata workshop). It also develops the interface between scientific analyses and management questions. To address this need, the NPLCC could serve as a "matchmaker":

> *Managers should have a place to ask questions without having to track down the particular scientists that can provide relevant support. If a manager can provide an overview of a problem and a list of unknowns, the NPLCC could dissect these needs and play matchmaker (Arcata workshop).*

To ensure efficient data collection, project participants also encouraged coordination of data collection. For example, field research could be more efficient if researchers could arrange to pick-up samples for other researchers, similar to a car-pool ride share site (Arcata workshop).

Project participants consistently identified low- or no-cost in-person meetings, workshops, seminars, and symposia as a high priority for the NPLCC because they are highly valuable and effective for addressing climate change issues.[83] Interdisciplinary training and research, for example, bridges the gap between climate research and other disciplines (NOAA, 2011, p. 17):

> *In terms of the terrestrial vs. aquatic boundaries, the NPLCC should try to bring the different types of science producers together so that marine biologists, aquatic biologists, and terrestrial ecologists – whether plant ecologists or others – so they could have a chance to sit down and think out the actions together. I think there is a real facilitation role for the NPLCC being there (Coastal Temperate Rainforest Ecosystem).*

Participants identified regional meetings organized by key ecosystems, ecoregions, or historic jurisdictions as important for affecting local decision making. Managers and indigenous communities in Alaska and British Columbia, for example, *need to have someone [perhaps a panel of experts] come and tell them more about climate change and the impacts that they will see (Alaska and British Columbia Coastal Freshwater).* Those working in the California Current Region also identified workshops with tribal communities as a potential priority for the NPLCC.

To respond to the overwhelming number of requests to participate in climate-related projects, participants suggested streamlined communications and improved coordination:

> *…I had someone in an Oregon state agency tell me they had been asked eleven times over the past year what kind of climate information they needed. There is some sort of disconnect and we need to figure out a way to reach out to people better without bothering them – do it more effectively. There are roadblocks, definitely a need for better coordination and communication (Columbia River Basin Freshwater).*

Finally, project participants identified a need to translate scientific results from one discipline into a format that is useful and relevant for those working in other disciplines or in management. Please see Chapter III.4, "Science communication and outreach," for more information.

Facilitate coordination, collaboration, and leveraging among institutions

Since the NPLCC is a partnership organization among many, diverse institutions, project participants identified facilitating coordination and collaboration within and across institutions as a key role for the NPLCC. NOAA also identified "cross-disciplinary coordination and collaboration across government agencies and with the private sector" as an example of interdisciplinary and integrated decision making approaches to addressing climate change (NOAA, 2011, p. 16). Specific roles suggested for the NPLCC include:

- Facilitate international coordination between U.S. and Canadian stakeholders to promote partnerships, and data and information sharing.

[83] Participants from the Puget Sound Georgia Basin Marine, California Current Marine #1, and Coastal Temperate Rainforest Ecosystem web-based focus groups, as well as the Juneau workshop, supported low- or no-cost in-person events as a high priority for the NPLCC.

- Facilitate coordination between research and management branches within institutions, as well as across institutions, to promote partnership and leverage resources.
- Highlight and share different vulnerabilities across the NPLCC to enable cross-ecosystem approaches to climate change work and identification of restoration priorities.

The barriers to coordination and collaboration between the U.S. and Canada are both physical and institutional. In southeast Alaska, for example, there is almost no cross-boundary international communications because icefields isolate the interior from the exterior (Juneau workshop). It is difficult, and sometimes not possible, to move funds across the border in either direction, which limits the ability to partner or leverage funding in support of collaborative U.S.-Canadian partnerships (Portland workshop). Data sets are also inconsistent, which inhibits development and implementation of cross-boundary decision-support systems, regional maps, tools, and scenarios data (Juneau workshop). For example, digital elevation and hydrography datasets are inconsistent across the U.S. and Canada (Juneau workshop).

As a result of these challenges, project participants suggest improving coordination across the U.S. and Canada by sharing relevant data sources on climate changes, producing an inventory of climate change data sources including metadata, replicating experiments in both countries, assistance with international travel, and standardization of measures and sampling design (Juneau workshop). Juneau workshop participants suggested the geographic focus should be LCC-wide for many data layers and at subregional scales in the vicinity of the Canadian border. The inventory of climate change data sources should include data from ten years ago, as well as a five-year forward plan to determine which data could be shared and to select priorities among them (Juneau workshop). Potential partners in this process include:

- National Oceanic and Atmospheric Administration (NOAA)
- U.S. and Canadian weather service bureaus
- The U.S. Geological Survey and the Geological Survey of Canada)
- The Scenarios Network for Alaska and Arctic Planning (SNAP)
- The Alaska Coastal Rainforest Center (ACRC) for GIS data integration
- The State of Alaska and Province of British Columbia
- Pacific Climate Impacts Consortium (PCIC) and Pacific Institute for Climate Solutions (PICS)
- Paul Hennon (U.S. Forest Service Pacific Northwest Research Station) and Ken Lertzman (Simon Fraser University) have developed ideas for shared research.
- Adaptation to Climate Change Team at Simon Fraser University

In addition to the challenges of cross-boundary work between the U.S. and Canada, project participants cited difficulty bridging research and management within and across agencies and institutions. Participants in the Portland and Arcata workshops noted that within a single agency, there is often a science-management division, but agencies within a state or Federal Department are often not aware of what their sister agencies are doing and their actions are not coordinated, and the problem simply gets more pronounced across states, State-Federal, and international divides. The NPLCC may be able to help by recognizing and leveraging the fact that different agencies and entities have unique mandates and objectives and by working to support those entities in meeting their individual goals through collaborative efforts (Portland workshop). For example, the NPLCC could facilitate the exchange and sharing of information by bringing agencies together (Arcata workshop). As a first step, the sharing of best practices was suggested (Portland workshop). This role for the NPLCC is also supported by those working in the California Current Region:

> *Biggest contribution of NPLCC is in the coordination realm between agencies, etc. There is a lot of info out there that spans entire California Current area and so coordination in type of data collected, funding, adaptation strategies, and outreach is a suggestion (California Current Marine #2).*

Specific products or outputs include a process for non-scientists to easily access studies from science organizations (e.g., NOAA) and a list of members and entities that are participating in the NPLCC, including where they store information (Arcata workshop). Participants also suggested that the NPLCC communicate their science needs to members, partners, and stakeholders (Arcata workshop). Each of these suggestions would enable managers and decision makers to more clearly understand climate change so they can make better-informed decisions, plan new policies, and adjust existing policies (Arcata workshop). Each of these suggestions also acknowledges the need to increase efficiency as funding declines:

> ―*.As our challenges as land managers increase while funding declines, we will need to become much more efficient at identifying priorities for ecological restoration and carrying out these projects in collaboration with multiple partners" (Survey Respondent 65).*

The NPLCC could also assist with efforts to identify and share vulnerabilities region-wide, which would facilitate cross-ecosystem approaches to climate change work and identification of priorities:

> *… I wonder if we could – across the LCC [and] that latitudinal gradient – if we could highlight and share the different vulnerabilities across the NPLCC and tune our way of thinking to what we are each seeing…across different organizations as vulnerabilities across the region (Coastal Temperate Rainforest Ecosystem).*

To capitalize on these suggestions, Arcata workshop participants suggested a multi-scale approach from the LCC-scale to subregional scales aligned with the timeline for revisions to policies and plans (e.g., 10-year, 20-year, etc.).

Facilitate coordination, collaboration, and leveraging of funding sources

Project participants suggested the NPLCC may be well-suited to identifying leverage opportunities for funding sources because the region covers a large geography and works with many partners that typically share some common goals. Leveraging funding sources would respond to the need to engage in planning and adaptation despite limited budgets:

> *…The question is how to do these things without millions of dollars to throw at the problem. The first step we tell people is to think about coordination – what are you already doing? How can you apply this to climate change? Kind of grab the low-hanging fruit… (Columbia River Basin Freshwater).*

For example, the NPLCC could help pair restoration and research:

> *To the extent that the NPLCC can facilitate… so that if someone has some funding for restoration and someone else has funding for research if there is a way to pair them up and get a bigger bang for the buck….to do that we have to know who to talk to and who might partner with the work that someone might be doing (California Current Marine #1).*

As Portland workshop participants suggested, the NPLCC could enable resource sharing among entities from both a bottom-up and a top-down approach. Both approaches would have to demonstrate tangible results and a return on investment for each partner; the NPLCC could assist with project design (Portland workshop). The top-down approach is to pool resources to address shared interests and NPLCC priorities, a suggestion also made during one web-based focus group:

> *… priorities for [the NPLCC] – help us find funding, for examples a list of funding opportunities for established priorities. We need partnership funding for policy makers, managers and scientists…Also help us coordinate (California Current Marine #1).*

The bottom-up approach is to identify and reduce institutional barriers to collaborating "scientist to scientist." This approach would also apply for NGOs, agencies, and other entities, as suggested in another web-based focus group:

> *…how can we work with partners to see where are priorities once we go through this process, where do they merge and where can we bring the most resources together to get the biggest bang for our buck on this landscape? Maybe a hydrology priority merging with where I need to make a connectivity investment merging with where an agency really needs to be looking at an issue… (Interior Mountain Ecosystems).*

Adaptation Marketplace is an online tool intended to assist funders in understanding climate change adaptation needs in a given region or sector. It provides information on the specific location, project focus, project leads, and level of needed funding for priority climate change adaptation projects and can assist efforts to streamline funding and investment in a region. The prototype is available currently for the Coral Triangle, a region north of Australia encompassing the tropical marine waters of Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste. Alex Score of EcoAdapt can be contacted for further information.

3. New or different science, data, or information

Eleven of thirteen web-based focus groups, all three workshops, and many survey respondents described the need for new or difference science, data, and information in the NPLCC region. Addressing this need would provide key inputs and guidance for the decision-support and capacity-building described in Sections 1 and 2 of this chapter, respectively. It would also improve understanding of how climate change may affect ecosystems, habitats, and species.

Incidence of Discussion of Need in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	✓
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	✓
Columbia River Basin	✓
WA/OR/n. CA Coastal Ranges and Drainages	✓
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	✓
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

Two primary principles to guide consideration of new or different science, data, or information were identified by project participants:

- Focus on generating "actionable-level information and analyses" that inform site-level projects and decisions.
- Produce science, data, and information in cooperation with decision makers because it is more useful for decision making when it is produced collaboratively.

These principles are consistent with those found in the literature on the co-production of knowledge (Cash et al. 2003, Karl et al. 2007, Lemos and Morehouse 2005, Roux et al. 2006) which asserts "…„co-production‟ of knowledge through collaborative learning between „experts‟ and „users‟ is a more suitable approach to building a knowledge system for the sustainable management of ecosystems" (Roux et al. 2006, p. 4). Usable knowledge, such as the "actionable-level information and analyses" identified by project participants refers to knowledge that "…can be incorporated into the decision-making processes of all stakeholders, and which enhances their ability to avoid, mitigate, or adapt to stressors in their environment" (Lemos and Morehouse 2005, p. 62).

The needs described in this section respond to the overarching challenges of ―*getting climate science information at the scale and resolution that is useful in making local land use decisions [and] lack of technical capacity to use modeling and mapping tools" (Survey Respondent 29).* Specific needs are:

- Fundamental or baseline data
- Models and downscaling
- Scenarios
- Cost estimates and cost-benefit analyses

Fundamental or baseline data

Survey respondents and web-based focus group participants from the Puget Sound and Georgia Basin Marine, Pacific Coast and Nass Ranges Freshwater, and Coastal Temperate Rainforest Ecosystem discussed the need for fundamental or baseline data to respond to a lack of monitoring data, *―lack of studies on many of the organisms we manage…" (Survey Respondent 63),* and *―…holes in our scientific knowledge regarding future climate change implications for various species and habitats…" (Survey Respondent 35).* Limited and short-term funding were also identified as key challenges to identifying, collecting, and using fundamental or baseline data (Survey Respondents 2 and 11). General needs include setting up baseline studies and basic GIS information:

> *I need ―…assistance in knowing how to set up baseline studies in a variety of habitats and ecosystems" (Survey Respondent 78).*
>
> *I think one thing that the LCC could do some value-added is develop some basic GIS information… Some areas where we work and manage a lot, we have really good data, but there is a broad area where we don't have data… (Coastal Temperate Rainforest Ecosystems).*

Project participants also identified data that is adequately addressed by existing partnerships and research efforts in the region. For example, fundamental snowpack and other hydrologic data in the Columbia River Basin are largely covered by existing efforts:

> *There is work already on snowpack inherent in all these projects, so you may not need to do another project, just tap into the work that's already being done in Washington, we're also doing some work. It's our #1 issue – water resources…Also Alan Hamlet's work – I know this is drawing from that… (Columbia River Basin Freshwater).*

More specific examples of requests for fundamental or baseline data in hydrology, coastal habitats and flooding, vegetation composition, and species hybridization are discussed in Chapters V.1 (p. 69), sections 1, 2, and 4 of Chapter VI (p. 89, 106, and 116), VII.1 (p. 121), and IX.1 (p. 168), respectively.

Models and downscaling

Project participants, particularly survey respondents, routinely identified the need for downscaled climate models in the NPLCC region.[84] Specific downscaling needs include:

- Downscale climate models to a particular location (Survey Respondents 34 & 35, WA/OR/n. CA Coastal Ranges and Drainages Freshwater, Arcata workshop). More specific modeling "*allow[s] us to understand in various scenarios how ecosystems will be affected" (Survey Respondent 30).*
- Develop "*multi-scale climate change downscaling tools" (Survey Respondent 71)* or vulnerability assessments (British Columbia Coast Marine)

[84] Project participants in all three workshops and eight of thirteen web-based focus groups also discussed downscaled climate models as a need: Southcentral and Southeast Alaska Marine, British Columbia Coast Marine, Puget Sound and Georgia Basin Marine, California Current Marine #2, Pacific Coast and Nass Ranges Freshwater, WA/OR/n. CA Coastal Ranges and Drainages Freshwater, Coastal Temperate Rainforest Ecosystems, and Lowlands, Prairies, and Other Non-forested Systems.

- *―Downscaled maps to the finest degree possible" (Survey Respondent 58).*

The models and downscaling participants requested would address research and management challenges in the NPLCC region including poor model quality, geographic scales that are too large for informing management, and model resolution that is too coarse for highly diverse landscapes. For example, it is difficult to base *―management decisions on forward-looking projections about the potential effects of climate change because the reliability of models of future conditions in the area is either unknown or such models are just now in development" (Survey Respondent 70).* The need to increase model reliability was also cited by web-based focus group participants from Alaska and California, who noted downscaled models are currently insufficient to affect or make decisions due to poor data quality and the uncertainty associated with poor data quality (Southcentral and Southeast Alaska Marine, Coastal Temperate Rainforest Ecosystems).

As one participant noted, computing power has always limited the ability to achieve higher resolution, but recent advances have enabled resolution down to tens of kilometers (Lowlands, Prairies, and Other Non-forested Systems). For example, *USGS has a great downscaled website…it has been very helpful [and has] 12 km downscaled meteorological data for all of the U.S. (California Current Marine #2).* Under the auspices of the "weatherathome" experiment on climateprediction.net program, researchers at Oregon State University are *…downscaling to 25 kilometers in the Western U.S., but [are] not to the future yet (Columbia River Basin Freshwater; hyperlink added).* The Geos Institute has downscaled climate information for the NPLCC region at 8 kilometer resolution; other data layers are downscaled to 1 kilometer resolution (DellaSala et al. *in review*). As the technology improves, researchers and managers will have access to more *―actionable level information and analyses, particularly best available downscaling and scenario planning that works for landowners/managers, communities, and conservation agencies" (Survey Respondent 78).*

While improved resolution, data quality, and data availability at fine geographic scales will address some of the challenges identified by project participants, there are several other challenges that require alternative approaches to address. Section 2 (p. 28) of this chapter reviews approaches for responding to challenges related to capacity-building and collaboration for modeling and downscaling efforts. These include several challenges related to models and downscaling such as:

- *―The variety and inhomogeneity in the resolution, driving data, assumptions, and quality associated with regional climate data, (downscaled or otherwise)" (Survey Respondent 46),* and
- The need to translate regional modeling outputs to site-level recommendations and work with resource managers or other non-modelers to ensure they have the correct model for their landscape (Survey Respondents 14 and 50, Lowlands, Prairies, and Other Non-forested Systems).

Finally, an overemphasis on downscaled information may occlude other important factors that determine current and potential landscape conditions. For example, one web-based focus group participant noted that there is…*too much emphasis on downscaling temperature and precipitation when [climate-related impacts to] land use has >50% influence on runoff (Pacific Coast and Nass Ranges Freshwater).*

More specific examples of requests for downscaled information for hydrology, coastal habitats, northwest California forests, and fish are discussed in Chapters V.1 (p. 69), VI.1 (p. 89), VII.3 (p. 136), and VIII.4 (p. 164), respectively.

Scenarios

The need to explore the range of possible futures using scenarios was identified by several survey respondents and six of thirteen web-based focus groups.[85] Project participants stated that scenarios are a compelling approach with decision makers and help inform management decisions. It is ideal for scenario information to be downloadable, not simply available in a PDF format (Pacific Coast and Nass Ranges Freshwater). For some participants, scenarios may be among the most helpful products for addressing climate change in the region:

> *Perhaps one of the most useful things coming out would actually be generating various scenarios of potential changes, a range of different future states… Quantifying expected ranges of variability is something that would be desirable and helpful for us to put into context the changes that we might be expecting to see with climate change… (Coastal Temperate Rainforest Ecosystems).*

> *… Trying to shift through all of those conflicting results, a lot of people are going have to synthesize that and come up with plausible scenarios (Lowlands, Prairies, and Other Non-forested Systems).*

Despite the recognized utility of scenarios, a few key challenges are inhibiting some from using scenarios in their work. These include a lack of knowledge about how to incorporate climate change and adaptation information into scenarios (British Columbia Coast Marine), difficulty knowing ―*…what scenarios will be relevant for our region and how to prioritize them" (Survey Respondent 43),* and the need to work with decision makers and partners to identify which types of scenarios to develop. The latter challenge is demonstrated by this example from the Puget Sound and Georgia Basin Marine web-based focus group:

> *… I think you can strive for an average scenario that you can run though. But the high and low scenarios really depend on what you are looking at. Needs differ between sectors… The element that [partners and decision makers] are investigating dictates where the high or low scenario will be due to their needs. Your best bet is to try and find a mid-range for everyone but the high and lows will have to be chosen based on the topic you are looking at (Puget Sound and Georgia Basin Marine).*

Assistance with scenario development or use is available from:

- Scenarios Network for Alaska and Arctic Planning (SNAP)
- University of Washington Climate Impacts Group (CIG)
- City and Borough of Juneau
- World Wildlife Fund Canada: James Casey is building a scenario for the lower Skeena watershed, but a coast-wide scenario is also needed (Pacific Coast and Nass Ranges Freshwater).
- Geos Institute: Two emissions scenarios (IPCC SRES A2A and A1B) and three General Circulation Models (CSIRO, CCCMA, HadCM3) have been downscaled for the NPLCC region.

[85] The six web-based focus groups represented are British Columbia Coast Marine, Puget Sound and Georgia Basin Marine, Pacific Coast and Nass Ranges Freshwater, Puget Sound and Georgia Basin Freshwater, Coastal Temperate Rainforest Ecosystems, and Lowlands, Prairies, and Other Non-forested Systems.

The scenarios and models have been used to test the Yale Adaptation Framework in Pacific coastal rainforests, a region with significant geographic overlap with the NPLCC region. The Framework uses available data to integrate the development of climate change adaptation strategies with natural resource planning and conservation (DellaSala et al. *in review*; contact: Dominick DellaSala).

- The Pacific Climate Impacts Consortium‟s (PCIC) Plan2Adapt use a mid-point value from a single scenario.[86]
- Environment Canada‟s Canadian Climate Change Scenarios Network (CCCSN) provides many scenarios and information on how to use them. For example, three scenarios are available at the provincial level, which helps communicate the range of possible impacts to the government (Pacific Coast and Nass Ranges Freshwater).

Additional examples of requests for scenario use and development can be found in chapters covering hydrology (Chapter V.1, p. 69), coastal habitats (Chapter VI.1, p. 89), phenology and food webs (Chapter VI.2, p. 106), changes in vegetation composition (Chapter VII.1, p. 121), northwest California forests (Chapter VII.3, p. 136), and the Willamette Valley (Chapter VII.5, p. 144).

Cost estimates and cost-benefit analyses

Cost estimates and cost-benefit analyses were identified as a need by several survey respondents, as well as web-based focus group participants from the California Current Marine #1 and Pacific Coast and Nass Ranges Freshwater focus groups. Project participants suggested producing cost estimates and cost-benefit analyses because *the costs of not implementing…for climate change are not taken into account (Pacific Coast and Nass Ranges Freshwater).* In addition, precedent-setting issues like climate change ―*…are perhaps best met with economic analyses showing net benefit of including climate change adaptation/mitigation" (Survey Respondent 57).* Specific research and topical focal areas include:

> ―*Amortized cost estimates (50-100 years) of land use changes relative to engineered solutions…" (Survey Respondent 29)*
>
> ―*…More research on the costs of climate impacts and the benefits of climate adaptation (including, but not limited to economic benefits)…" (Survey Respondent 55).*
>
> *…the costs of climate change and how it is impacting industry – the economic costs of climate change… (Pacific Coast and Nass Ranges Freshwater).*
>
> *…Cost benefit and risk analysis, especially for climate skeptics. The cost of not doing anything and other scenarios, especially at the tax parcel level. There was a tool in MA that looked at things on a parcel basis that was helpful there (California Current #1).*

Additional examples of requests for cost estimates or cost-benefit analyses are discussed in Chapter VI.4, "Inform cost estimates and vulnerability assessments related to altered coastal flooding regimes in Puget Sound and the California Current Region."

[86] The mid-point value is the ensemble median "from a PCIC standard set of Global Climate Model (GCM) projections" (Pacific Climate Impacts Consortium, Plan2Adapt, accessed July 23, 2012 from http://plan2adapt.ca/tools/planners).

4. Science communication and outreach

Project participants suggested a number of potential roles for the NPLCC in enhancing, expanding, and coordinating science communication and outreach. These range from basic outreach for those working on climate change issues to translating climate change information for use by the public and creating a narrative for the political discussion of climate change. Eight of thirteen web-based focus groups,[87] the Juneau and Arcata workshops, and several survey respondents discussed science communication and outreach. Participants identified several guiding principles for improving communication and outreach in the NPLCC region:

Incidence of Discussion of Need in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	✓
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	✓
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	✓
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	
Juneau Workshop	✓
Arcata Workshop	✓

- Define and prioritize key audiences, and create a unique, targeted message for each.
- Use "good, consistent language" in communication and outreach materials. For example:

  I think we'd be better off speaking a language everybody could understand and then have a set of analytical tools that we could use to talk to non-scientists (Interior Mountain Ecosystems).

- Construct messages that go from "end to end," for example from the physics of climate change to the effects on phytoplankton, fisheries, people, communities, and the economy.
- Find appropriate messengers for each target audience. They may or may not be scientists.
- Recognize that science does not determine decisions, values do.
- Focus on what the NPLCC can facilitate getting accomplished in the region, rather than what it could do.

These principles provide context and guidance for science communication and outreach with the three audiences discussed in this section.

[87] The eight web-based focus groups represented are Southcentral and Southeast Alaska Marine, British Columbia Coast Marine, Puget Sound and Georgia Basin Marine, California Current Marine #1 and #2, Alaska and British Columbia Coastal Freshwater, Pacific Coast and Nass Ranges Freshwater, and Puget Sound and Georgia Basin Freshwater.

Resource managers, conservation practitioners, and researchers

Given the significant diversity in resource issues and ecosystem dynamics in the NPLCC region, project participants requested assistance translating and using the results of scientific research from other disciplines, incorporating the lessons learned from management approaches utilized elsewhere in the region, and basic outreach to notify peers and colleagues of new information that may be useful in their work. Most comments are from marine ecosystem web-based focus groups, as well as the Arcata workshop.[88]

Translating and using the results of scientific research would help resource managers incorporate climate change into their work. For example, a discharge analysis from the Nisqually River in Washington State could inform decisions associated with flood regimes:

> *The largest question from program staff is how to incorporate climate change into my work. First step is awareness. A slide they like to use is the discharge analysis from Nisqually… When we look at data to calculate 100 year floods, the [discharge analysis shows] they now occur every 15 years….I think overall sharing these communication tools would be helpful… (Puget Sound and Georgia Basin Marine).*

Incorporating the lessons learned from management approaches utilized elsewhere in the NPLCC region would provide needed information to stakeholders with limited capacity such as many local tribes and governments:

> *…Also it would be good to see a group like NPLCC engage at the end of the report with some outreach to local tribes and governments who need this information. So that they know where they can go to find the information and that it is current (California Current Marine #1).*

Finally, basic outreach to local, regional, and other partners would keep stakeholders informed and aware of information that could assist them in their work. For example, the NPLCC could assist NGOs in their efforts to distribute information and products, as well as inform partners about the NPLCC"s 10-year strategic plan:

- *..NPLCC [could] support getting NGOs' rich information (e.g., translating science for policy, policy-relevant, and decision-relevant information) out to partners. I think that there is a lot of work out there that would advise us in this effort (California Current Marine #2)*
- Translate the information tools and the 10-yr strategic plan to land managers and planning commissions, private landowners, and civil servants, i.e., providing training on tools, adaptation strategies, and case studies. The NPLCC could lead local/regional outreach (Arcata workshop).

The public and educators

Project participants in four of thirteen web-based focus groups,[89] the Juneau and Arcata workshops, and the survey emphasized the need to communicate with the public and educators to reduce the negative

[88] Specifically, the web-based focus groups represented are the Puget Sound and Georgia Basin Marine and the two California Current marine ecosystem focus groups.

perception of science, mitigate disinformation to the public, and inform the next generation about climate change and related concerns:

> *… The first message that we convey to the public is a negative one…We need to educate instead of scare the public… Somehow we need to change the message so that people understand the science of climate change instead of the negative (California Current Marine #1).*

> *In terms of coordination, collaboration and communication, we have heard: ―how do you translate it to classrooms?" So you are not talking to scientists but to the future (Southcentral and Southeast Alaska Marine).*

To address negative messaging and reach a wide variety of audiences, the Western Association of Fish and Wildlife Agencies (2012) suggests three strategies for positively communicating state agency efforts on climate change:

- Discuss existing projects in terms of their climate co-benefits or actions (WAFWA, 2012, p. 4).
- Demonstrate how management actions for endemic and priority species are incorporating climate change science. This includes evaluation and modification of management actions, as well as building in adaptive management strategies (WAFWA, 2012, p. 4).
- Utilize a risk management approach to describe climate adaptation activities because "it is pragmatic and sound management practice to fully evaluate future climate risks when designing new projects or developing management plans in order to ensure the value of our investments over the long term" (WAFWA, 2012, p. 4)

Through webinars, conference calls, or other collaborative methods open to all, the NPLCC would provide a credible venue for designing education and outreach activities that galvanize action (Portland workshop). Participants emphasized connecting and organizing with people on the ground is the key to moving forward and could help bridge the divide between urban and rural values:

> *We do really need to get the public behind the idea that climate change is going to impact you. That is how we will get the regulation to change the legislature to change things that are not working in different laws (California Current Marine #2).*

> *Action really comes when people are involved. How can we quantify the information to include humans so that we can move forward without having to have an emergency to validate the act? How do we make the information applicable to people in general? (British Columbia Coast Marine).*

> *The NPLCC could assist with crossing the ―boundary between urban and rural – different values" (Arcata workshop).*

Within the primary and secondary school system, the NPLCC could work with existing school programs and coordinate efforts with science teachers to communicate the challenges facing aquatic and terrestrial

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[89] The four web-based focus groups represented are Southcentral and Southeast Alaska Marine, California Current Marine #1 and #2, and Alaska and British Columbia Coastal Freshwater.

ecosystems. Juneau workshop participants suggested a careful consideration of how to present information. Options include seasonal and cultural approaches, as well as approaches tailored to grade level or audience. All of these suggestions are for the purpose of expanding knowledge and causing students to ask questions (Juneau workshop).

The NPLCC could also provide a "professional go-to location" for educators to look up information, a place where "people can feel confident there is good quality control" (Arcata workshop).

As participants in the Arcata workshop noted, another source of information to classrooms are resource extractors because they hold a wealth of information about natural systems. The NPLCC could gather and integrate information from resource extractors including fishers, hunters, loggers, and aquaculturalists, then disseminate to schools (Arcata workshop). Finally, one survey respondent noted *―public education at the secondary school level needs to be funded to equip the next generation with the knowledge and tools to deal with this future catastrophe" (Survey Respondent 39).*

Decision makers

Project participants suggested a number of communication, outreach, and translation activities to bridge gaps between politics and science. Five of thirteen web-based focus groups are represented,[90] as well as several survey respondents and participants in the Arcata workshop. Project participants also noted the NPLCC could serve as an "honest broker" – a credible source of climate change information. These included demonstrating how a management decision can impact the climate and providing a narrative for the political discussion around climate change. In the latter capacity, the NPLCC could help identify the top three to five issues and connect them to policy and monitoring:

> *NPLCC could help create the narrative to the political component. One of the great opportunities is to inform the policy conversation: ―here are the things that are most important" and translating that into funding. How much [can they] limit it to the top 3-5 issues for certain years? If you include too many issues people's eyes glaze over so if we can highlight priorities and connect it to policy and monitoring they can impact the broader conversation (California Current Marine #2).*

Workshop participants suggested the NPLCC could assist with increasing understanding of the link between ecological and conservation issues and outcomes with their economic and human impacts. This would reduce the perceived tension between conservation and economics, and support proactive responses to climate change:

> *…Even if we know that the longer term is important it is hard to incorporate that. We don't have the opportunity to push for proactive approaches (California Current Marine #1).*

[90] The web-based focus groups represented are British Columbia Coast Marine, California Current Marine #1 and #2, Pacific Coast and Nass Ranges Freshwater, and Puget Sound and Georgia Basin Freshwater.

Web-based focus group participants, particularly those working in British Columbia and areas south, requested assistance communicating climate change to decision makers to galvanize action:

> *[We] need tools and data not in the nitty gritty details but —how do we present this" that communicate to the general public and to the decision makers. I know there are tools out there. The largest challenge will be to see if we can get local municipal government to take it seriously and change their planning documents (California Current Marine #2).*

A specific suggestion was to produce short communications that clearly articulate problems and solutions and are produced via collaboration among government, NGOs, and academia:

> *We struggle with communicating effectively with decision makers…Producing those summaries that [make it] clear to decision makers that their change in management can impact the climate – targeted communication as well as facilitating collaboration (Pacific Coast and Nass Ranges Freshwater).*

These suggestions respond to specific challenges participants identified. For example, they respond to a lack of political will and barriers to long-term planning:

> *—In addition to a lack of site specific science, more broadly there is a lack of specific tools and associated regulatory frameworks (and political will) for local and regional decision makers to use to take action" (Survey Respondent 8).*

> *…But the real challenge is the political. What are the tools that can help us bring this information to policymakers? How is the land zoned next and how to communicate with local decision makers? Many are under coastal act permitting or local city and county planning and zoning. It is hard to get the planning documents to do anything that looks 10 years ahead, let alone longer ahead… (California Current Marine #2).*

IV. Activity Areas for Indigenous Natural and Cultural Resources[91]

Tribes, Alaska Natives, and First Nations identified a range of projects and activities to address the challenges associated with sustaining their Way of Life given current and potential future climate change effects on ecosystems, habitats, and species. Other project participants also highlighted a number of opportunities associated with addressing climate change effects on indigenous natural and cultural resources. Most suggestions focus on species and habitats that are culturally and economically significant natural and cultural resources, identifying if and how to incorporate traditional ecological knowledge and western science in the NPLCC"s work, and increasing collaboration, both within formal Government-to-Government relationships and through less formal means (Box 5, p. 61). These activity areas are captured in the following statement from one web-based focus group participant:

> *…Working for a tribe, we tend to focus on culturally significant species of concern, but those species require a whole matrix of habitat. To me, that is the key thing the LCC really brings to the larger climate change discussion is really focusing at that habitat-ecosystem level and I think it fits well within the mandate of Fish and Wildlife too. That's what supports the fish and wildlife that we care about… (Coastal Temperate Rainforest Ecosystem).*

The activity areas are:

1. Support the efforts of Tribes, Alaska Natives, and First Nations to identify and address climate-related priorities related to decision-support and capacity-building
2. Research to understand and assess climate change effects on the Indigenous Way of Life

Within an activity area, several specific activities requested by project participants are described. The description includes information on how many project participants identified the activity and the climate change-related challenges associated with pursuing the activity. To provide information to the NPLCC about when, where, and under what circumstances support is requested, participant evaluations of the activity across the four evaluation criteria are synthesized:

- *Decision-relevance* indicates which decisions the activity would help inform or guide.
- *Timeline or sense of urgency* indicates when the activity is needed and provides a sense of why and how important, or urgent, it is to pursue the activity.
- *Spatial and temporal scale* identifies the necessary geographic region or spatial coverage for the activity and whether the activity is needed on an annual, seasonal, daily, etc. timescale.
- *Partners and ongoing efforts* identifies the people, partnerships, and organizations that might already have information about the activity or might be well suited to develop it.

[91] Special thanks are due to Kathy Lynn (Tribal Climate Change Project Coordinator, University of Oregon) and Garrit Voggesser (National Director for Tribal Partnerships, National Wildlife Federation), who provided extensive review and iterative revision of this chapter.

1. Support the efforts of Tribes, Alaska Natives, and First Nations to identify and address climate-related priorities related to decision-support and capacity-building

Project participants throughout the NPLCC region requested capacity-building and decision-support to identify and address climate-related priorities of Tribes, Alaska Natives, and First Nations in the NPLCC region. Suggestions range from incorporating traditional ecological knowledge and western science to providing training and professional development within tribes, facilitating collaboration between tribes and other entities, and supporting efforts to protect trust resources. Specific activities are:

- Support efforts to identify if and how to incorporate traditional ecological knowledge and western science in the NPLCC‟s work
- Support training and other capacity-building within Tribes
- Facilitate collaboration and communication between Tribes and resource agencies
- Facilitate science communication with the public, educators, and decision makers
- Protect tribal lands, trust resources, and tribal rights

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	
Columbia River Basin	✓
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

Support efforts to identify if and how to incorporate traditional ecological knowledge and western science in the NPLCC’s work

Project participants representing Tribes, Alaska Natives, First Nations, federal agencies, conservation organizations, and universities requested a focus on discussing and identifying if and how to incorporate traditional ecological knowledge and western science in the NPLCC‟s work (Southcentral and Southeast Alaska Marine, California Current Marine #1, Portland workshop, Juneau workshop, Arcata workshop, Survey Respondent 76). Several participants stated western science and traditional knowledge may be incompatible in some or all situations and that integrating the two may be unsuccessful given the different cultural backgrounds of each way of knowing (Juneau workshop, Arcata workshop). Since traditional ecological knowledge is culturally sensitive and proprietary, strategies are needed to ensure the sharing of traditional knowledge is led by indigenous communities (Juneau workshop, Arcata workshop). Further, project participants noted that when the decision to share traditional knowledge is made, explicit attention to *how* that knowledge is shared is essential. For example, the sharing of traditional ecological knowledge could occur through formal agreements that ensure tribes and traditional knowledge holders decide how information is used and shared. The Principle of Free Prior and Informed Consent (Word doc, 123 KB) and the United Nations Declaration on the Rights of Indigenous Peoples (adopted by the General Assembly in 2007) are two mechanisms that help protect traditional knowledge and inform efforts to protect culturally sensitive information (Juneau workshop).

Despite the possibility that traditional knowledge and western science may be incompatible and the challenges associated with incorporating or integrating traditional knowledge and western science in the NPLCC"s work, many participants expressed an interest in trying (Southcentral and Southeast Alaska Marine, California Current Marine #1, Portland workshop, Juneau workshop, Arcata workshop, Survey Respondent 76). In fact, project participants identified several characteristics of traditional knowledge and indigenous decision-making that are particularly helpful and relevant for addressing climate change (Coastal Temperate Rainforest Ecosystem, Juneau workshop, Arcata workshop):

- The long time scale – going back thousands of years – for which knowledge of climatic changes, climate-related impacts and management response is available.
- The long time scale – going forward several generations – indigenous communities use to determine the costs and benefits of present-day actions and plan for future impacts.
- The integration of environmental, social, and economic impacts in decision-making remains a challenge for much of western science, but is often a key feature of decision-making in indigenous communities.

Further, project participants suggested incorporating traditional and local knowledge in order to understand which changes are most important at local and human scales and to make decisions that meet cross-cultural needs (Juneau workshop). Local knowledge, for example, can complement knowledge from indigenous communities, as it is also place-based and reflects knowledge gathered by a community over time. Structured approaches can be set up to gather information. For example, a focus on the local and human scale would provide data that can apply broadly to issues of local importance and inform communities about immediate impacts (Juneau workshop). The sense of urgency is higher in locations where villages are already being relocated (e.g., western coastal Alaska), and is high throughout the NPLCC region because elders are passing on (Juneau workshop).

Project participants provided three specific suggestions for how to incorporate or integrate traditional ecological knowledge and western science:

- *—.Methodology and examples of incorporating traditional ecological knowledge into the processes that research scientists utilize in conducting credible research" (Survey Respondent 76).*
- Inclusion of the Indigenous Environmental Network and their science and traditional ecological knowledge (Arcata workshop).
- Inclusion of the international indigenous entities and mechanisms that address climate change experience and human impacts (Arcata workshop). These include the International Indian Treaty Council, United Nations Declaration on the Rights of Indigenous Peoples (PDF, 165 KB),

Principle of Free Prior and Informed Consent (Word doc, 123 KB), and the Indigenous Peoples Global Summit on Climate Change (2009; links to report on summit, PDF, ~870 KB).

Acting on the latter two suggestions would provide information on the historical and current experience of indigenous peoples with government agencies, industry, and others (Arcata workshop), while acting on the first suggestion would provide tangible examples of progress or success in incorporating traditional knowledge and western science in the NPLCC"s work. Participants in the Arcata workshop noted information on traditional ecological knowledge is a prerequisite to decision making.

The spatial scale for these activities is NPLCC-wide, with a focus on coastal areas and communities (Juneau workshop). It will take time for the scientific and academic communities to interact with local and Native cultures, but some of the information is already available and could be brought forward immediately (Juneau workshop, Arcata workshop). Any testing related to indigenous knowledge should be ongoing and capture seasonal as well as annual change (Arcata workshop).

Several partners and ongoing efforts were identified by project participants. Ongoing efforts include these seven examples of working with indigenous communities and traditional knowledge:

- *…There are a couple of initiatives that I am aware of – in the summer a tribe symposium to look at climate change and to see how coastal communities can deal with that and how tribes and western science can incorporate traditional ecological knowledge into management… (California Current Marine #1).* The participant is referring to the First Stewards Symposium, which took place in Washington, DC from July 17-20, 2012. Information on panelists, video from the symposium, several blogs, and other materials are available on the website.
- The Karuk Tribe is engaged in a collaborative partnership with several universities including the University of California Berkeley, Whitman College, University of Oregon, and Humboldt State University. This is a partnership between academia and traditional knowledge holders (Arcata workshop).
- The Bering Sea Project interviewed community members about their experiences in Alaska (Southcentral and Southeast Alaska Marine).
- The Alaska Native Harbor Seal Commission and university researchers partnered to collect tissue samples from animals caught for subsistence (Southcentral and Southeast Alaska Marine).
- The Alaska Coastal Rainforest Center"s Symposium *Integrating Science, Resource Management, and Communities* and other workshops included the melding of traditional ecological knowledge and western science (Juneau workshop).
- The Pacific Northwest Tribal Climate Change Project produced a draft report entitled *A Synthesis of Literature on Traditional Ecological Knowledge and Climate Change* (PDF, 357 KB). The report provides information on the role of traditional knowledge in climate change adaptation, integration of traditional ecological knowledge and western science including protection of native knowledge systems and culture, and policy considerations for integrating traditional ecological knowledge within climate change initiatives.
- *…We are doing a project on climate change and traditional knowledge – incorporating traditional ecological knowledge into western science – and using traditional stories to convey information on climate change. We are working with anthropologists on it. It could bring to light knowledge of history and science. They can relate better to the*

cultural knowledge than the science so it could be a powerful tool… (Southcentral and Southeast Alaska Marine).

The NPLCC has also funded projects that "address using traditional ecological knowledge, where appropriate, to help inform natural and cultural resource management." The projects also seek to identify unmet needs associated with addressing climate change effects on natural and cultural resources of Tribes, Alaska Natives, and First Nations. To ensure the sharing of traditional ecological knowledge, which is culturally-sensitive and proprietary, is a decision made by indigenous communities, those who received funding will decide what to share and how to share project results and information. Results and information that are shared will be communicated throughout the region and will inform NPLCC priorities. Seven projects were funded in 2012:

- Determine if climate change can affect the gathering calendar and natural resources. Project Lead is the Organized Village of Kasaan.
- Implementing ecosystem-based management in the central coast of British Columbia: Support for Heiltsuk participation in strategic landscape reserve design process. Project Lead is the Heiltsuk Integrated Resource Management Department.
- Correlation and climate sensitivity of human health and environmental indicators in the Salish Sea. Project Lead is the Swinomish Tribe.
- Gathering Our Thoughts: Tribal recommendations on a traditional knowledge management framework for the NPLCC. Project Lead is The Tulalip Tribes.
- Preserving Tribal Self-Determination and Knowledge Sovereignty While Expanding Use of Tribal Knowledge and Management in Off Reservation Lands in the Face of Climate Change. Project Lead is the Karuk Tribe.
- Utilizing Yurok traditional ecological knowledge to inform climate change priorities. Project Lead is the Yurok Tribe.
- Using TEK to model the effects of climate change and sea-level rise on coastal cultural resources at Tolowa Dunes State Park, CA. Project Lead is the California Department of Parks and Recreation.

Support training and other capacity-building within Tribes

Project participants stated that tribal capacity to address climate change varies by tribe, with some tribes in the NPLCC region just beginning to address climate change and others leading the way with innovative approaches to climate change adaptation.[92] Project participants suggested support for tribal capacity should be targeted to assist tribes along the spectrum of climate change knowledge and preparedness.

Several project participants suggested training and other capacity-building activities with tribes such as hosting conferences and workshops or providing access to data and tools:

What I would see as a priority for the NPLCC is facilitating workshops or something like that to go to tribal communities and working to see what is known about what changes

[92] Systematic variation in tribal climate change preparedness was not assessed by this project and may be an area for further study.

are occurring across local scales. [This includes the] resources that are associated with that… (California Current Marine #1).

[for the Tribes I work with] having much more specific information about where data is available for the various regions throughout the NPLCC [would be helpful] because they are varied in the coastal areas – what do tools and datasets provide for each region? (California Current Marine #2).

Tools and guidance to support decision making were also suggested. For example, providing baseline information and future projections for stream tributaries in key watersheds could form the basis of recommendations and guidance to respond to climate change effects in the future:

…look at a specific area, maybe where stream tributaries are going to change, look at upland effects, kind of produce that baseline and projection in the future. Maybe go from there and make recommendations on actions that can adjust to these effects in the future. Something like that probably goes a long way – something we can take to our tribes lends a bit more credibility when we go to our tribes, something like that from the LCC (Columbia River Basin Freshwater).

Training and associated capacity-building would address the varying capacities within tribes to address climate change effects on cultural and natural resources:

Each tribe has different management needs, priorities and impacts from climate change. Without those who are educated on climate change on staff it is hard to figure out what the information needs and tools are… (California Current Marine #1).

Project participants working with First Nations and other communities in British Columbia support a focus at the local and community level because *there is nothing happening at the federal or provincial level… but at local level, there are incredible opportunities (Pacific Coast and Nass Ranges Freshwater).* They noted the …*Columbia Basin Trust has done a great job of putting up resources to help communities think about including climate change into their planning (Pacific Coast and Nass Ranges Freshwater),* which indicates the Columbia Basin Trust may be an ongoing effort that could assist with training and capacity-building. Additional ongoing efforts that could assist with training and capacity-building include:

- The Institute for Tribal Environmental Professionals Climate Change Program, which offers climate change trainings, webinars, a monthly newsletter, a website entitled Tribes and Climate Change, and other projects and activities.
- The Centre for Indigenous Environmental Resources produced six Guidebooks to assist First Nations in climate change planning efforts. They are available in English and French. They also have a website entitled Taking Action on Climate Change, which includes information on current initiatives, partnership opportunities, past projects, and workshops.
- The American Indian/Alaska Native Climate Change Working Group is a newly formed social network of American Indians and Alaska Natives addressing climate change issues.

Facilitate collaboration and communication between Tribes and resource agencies

Collaborative initiatives among tribes and resource agencies were suggested by several project participants throughout the NPLCC region (Southcentral and Southeast Alaska Marine, California Current Marine #2, Pacific Coast and Nass Ranges Freshwater, Juneau workshop, Survey Respondent 28). For example:

> *―Collaborative programs between the federal, state, local agencies and the tribes are valuable to us because it ensures that we can both represent our member tribes in these larger endeavors, and avoid duplication of effort...” (Survey Respondent 28).*

In the United States, collaboration and communication can strengthen formal consultation processes and the Government-to-Government relationship between the U.S. government and federally-recognized tribes (Box 5, p. 61). Consultation is a useful tool for advancing collaborative planning and decision-making because it can build trust and respect among tribal, state, and federal partners engaged in the NPLCC (Lynn 2012, Lynn and Zakai 2012). Similarly, effective collaboration and communication enhances federal-tribal consultation through strong relationships and respect between sovereign governments (Lynn 2012, Lynn and Zakai 2012). Collaboration would assist with identification of baselines, corridors, and landscape conservation decisions and would facilitate sharing, where desired and approved by indigenous communities, of traditional knowledge as well as local, on-the-ground information. The NPLCC could assist with connecting the appropriate contacts within Tribes, Native Alaskan communities, and First Nations to address specific climate change impacts (California Current Marine #2, Pacific Coast and Nass Ranges Freshwater, Juneau workshop):

> *…some direct connections for the tribes to work with the scientists – vulnerability assessments, etc. They could help scientists and making connections with others, for example on-the-ground practitioners. [This would] help scientists to meet their needs – connect tribes with scientists. (California Current Marine #2)*

> *Try to bring First Nations more into the discussion on climate change. Bring local expertise and experience to help… (Pacific Coast and Nass Ranges Freshwater).*

The spatial scale is NPLCC-wide, extending from the biome to the local level. Information should be grouped by ecoregion and should emphasize the linkages among ecosystems (Juneau workshop). The temporal scale should focus on the next twenty years (Juneau workshop).

Potential partners and ongoing efforts include the Alaska Coastal Rainforest Center and their existing data integration efforts, the Essential Fish Habitat Review, research institutions, and tribes. Specific tribal collaborations include:

- The Pacific Northwest Tribal Climate Change Network (contact: Kathy Lynn, Tribal Climate Change Project Coordinator) meets every six to eight weeks to discuss and collaborate on issues relevant to Pacific Northwest tribes.

- The Institute for Tribal Environmental Professionals engages in collaboration regionally through the Southwest Tribal Climate Change Network as well as nationally through their websites, newsletters, and many activities and projects (contact: Sue Wotkyns, Climate Change Program).
- The Central Council Tlingit and Haida Indian Tribes of Alaska (CCTHITA) hold monthly teleconferences, produce quarterly newsletters, and partner with other tribal communities:

  —Central Council Tlingit and Haida hosts monthly teleconference, provides quarterly newsletters and we partner with the Ketchikan Indian Community to provide information on their website called Alaska Environmental Exchange website, www.alaskaee.com and the CCTHITA website. www.ccthita.org" (Survey Respondent 21).

Facilitate science communication with the public, educators, and decision makers

Project participants from Alaska and British Columbia suggested the tribes or the NPLCC could assist with science communication and outreach with the public, educators, and decision makers. Two examples were provided.

First, the NPLCC may serve as an effective coordinator of local-level testimonies of climate change (Juneau workshop). Testimonies may include information on what indigenous communities identify as climate change, signs of climate change "in our backyard," the role of climate change as a global stressor (i.e., "One Earth, One Impact"), the effects of changes in glaciers and land use such as logging, and related consequences and responses. This could occur with Tribal Councils, at Tribal Gatherings, within the educational system, through youth-based programs, or through field-based activities (Juneau workshop). This is a high-priority "Call for Action" throughout the NPLCC region (Juneau workshop). Potential partners and ongoing efforts include schools, Local Environmental Observers, Washington and Alaska Sea Grant, the National Science Foundation‟s GK-12 program, and the Alaska Center for Climate Assessment and Policy (ACCAP).

Box 5. Federally Recognized Tribes in the United States: Government-to-Government Relationship, Consultation, and Trust Resources

In the United States, federally recognized tribes have a Government-to-Government relationship with the U.S. government. This means the U.S. government and tribes should interact through processes and protocols that reflect relationships between political sovereigns.

Consultation is one important and essential process that enables federally recognized tribes and the U.S. government to identify and resolve issues that will affect tribes, tribal territory, and tribal resources. The Government-to-Government relationship and consultation obligations are described in the U.S. Constitution and numerous treaties, federal statutes and case law, executive orders, and regulations.

The U.S. government also holds tribal lands and resources in trust and is required by law to maintain health and access to those resources for federally recognized tribes in perpetuity. Where tribal lands and resources are located off-reservation, the federal government has a trust responsibility to uphold tribal treaty access to these lands and resources, which are known as Usual and Accustomed areas.

Sources: Lynn (2012). Lynn & Zakai (2012).

In the second example, First Nations were identified as a key constituency for overcoming political barriers to climate change adaptation and related efforts. As one web-based focus group stated, First Nations can assist in *…reaching the federal government…how do you get past the arguments against climate change? First Nations could add a lot to that direction (Pacific Coast and Nass Ranges Freshwater).*

Protect tribal lands, trust resources and tribal rights

Several project participants discussed the need to protect tribal lands, cultural and natural resources, and tribal rights in the NPLCC region (Box 5, p. 61):

> *Within territory, how might climate change affect territory? [There is an] emphasis on salmon and water but others are important, e.g. forest, food products, [and] iconic species like grizzlies (Pacific Coast and Nass Ranges Freshwater).*
>
> *…When climate change takes away cultural resources such as salmon and plants, could this be viewed as infringing on native rights – should the government not act to prevent it? … (Pacific Coast and Nass Ranges Freshwater).*
>
> *[Tribes] have a unique relationship with this area and the basin and do have treaty rights to fish in their Usual and Accustomed grounds. For them it's of such cultural importance – it's really their livelihood and their life that is tied to the rivers in the region (Columbia River Basin Freshwater).*

Portland workshop participants noted that over the next seven decades, pH is projected to decline in the south Puget Sound in Washington State, potentially impacting tribal trust resources in the region. Workshop participants identified protecting trust resources in the south Puget Sound as critical for the region, noting that non-climate stressors can influence pH and may offer a way to mitigate projected declines. Participants suggested the National Pollutant Discharge Elimination System (NPDES) permitting process as a possible avenue for mitigating pH declines in the south Puget Sound. The Washington Department of Ecology, U.S. Environmental Protection Agency, academia, federal agencies, and tribes were identified as partners in this effort.

2. Conduct research to understand and assess climate change effects on the Indigenous Way of Life

Project participants from throughout the NPLCC region, and representing a variety of tribal and non-tribal entities, repeatedly identified additional research to understand and assess climate change effects on the Indigenous Way of Life as a key activity area. Research would address a number of specific concerns raised by project participants representing indigenous communities or who work with indigenous communities including the effects of climate change on food security and cultural and natural resources:

> *The Chiefs are concerned with food security and how climate change will affect their traditional food such as salmon and moose as well as medicinal plants and berries… (Pacific Coast and Nass Ranges Freshwater).*

> *…Tribes are concerned about how climate change will impact their area. How might it impact the forest, or other species that they hold important for food or cultural reasons? … (Pacific Coast and Nass Ranges Freshwater).*

> *…[Tribes] have a unique relationship with this area and the basin and do have treaty rights to fish in their Usual and Accustomed grounds. For them it's of such cultural importance – it's really their livelihood and their life that is tied to the rivers in the region (Columbia River Basin Freshwater).*

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	
Columbia River Basin	✓
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	
Juneau Workshop	✓
Arcata Workshop	✓

To ensure the sharing of research findings and data on climate change effects on the Indigenous Way of Life respects and protects traditional ecological knowledge, which is proprietary and culturally-sensitive, indigenous communities should lead decision-making processes regarding the use and dissemination of this information (Box 5, p. 61).

For more information on challenges, opportunities, and needs identified by project participants related to the tribal trust responsibility, tribal rights, and climate change effects on Usual and Accustomed Areas, see Chapter IV.1 (p. 55). This section pertains specifically to conducting research and using data to better understand climate change effects on the Indigenous Way of Life.

Specific activities are:

- Research to assess and identify the most vulnerable cultural and natural resources
- Produce data and research that enables decision makers to work together to address climate change effects

Research to assess and identify the most vulnerable cultural and natural resources

To assess and identify the most vulnerable cultural and natural resources, project participants are asking a number of targeted questions about climate change effects and related vulnerability:

- What is the human impact on the land, sea, air, and habitats that directly or indirectly affects traditional food sources? (Arcata workshop)
- Are our shorelines warmer and how are they affecting our gathering of fish, shellfish, and seals (Juneau workshop)?
- Which fish populations are going to be viable into the future and which are not and what can we do to try to mitigate and adapt to that? (Columbia River Basin Freshwater).
- How might hatchery programs be affected by climate change? For example, ―*.are hatcheries sited in areas where water temperatures will be too warm in the future?...” (Survey Respondent 28).*
- *…When was the last big climate change that we experienced? That was at the end of the Pleistocene. I‘m just wondering if there isn‘t something we can learn from paleoecology specifically for terrestrial systems…? (Coastal Temperate Rainforest Ecosystem).*
- *Within territory, how might climate change affect territory? [There is an] emphasis on salmon and water but others are important, e.g. forest, food products, [and] iconic species like grizzlies (Pacific Coast and Nass Ranges Freshwater).*
- Which cultural resources are most vulnerable (Juneau workshop)?

Models are one method to answer questions about where and when species are likely to be vulnerable to climate change effects, but other methods are likely needed to address uncertainty in modeling results:

> *…There is a lot of difference between, say, a lower elevation east side area and a higher elevation. That‘s what‘s kind of hard to tease out because we know temperatures are going to go up, water temperatures are going to go up in the summer, flows are going to be diminished, but it‘s really hard to anticipate how those changes are going to affect our tribes because they cover such a large area. Some populations will probably do better than others – we know that will be true. To get to the answer to do that, there is a lot of modeling involved. You have to know how the climate‘s going to change, how hydrology is going to change, how water quality is going to change, and also the fish response. It builds in – not to bring that word up again – a lot of uncertainty in the end result… (Columbia River Basin Freshwater).*

Addressing the questions posed by project participants would provide baseline data on the health of a species or ecosystem and is critical to identify what foods are not healthy to consume (Juneau workshop, Arcata workshop). It would therefore inform consumption and recreation decisions that affect people and their communities (Juneau workshop, Arcata workshop). For example, since climate change is occurring fairly rapidly, gathering times should to be determined in order to ensure safety and health (Juneau workshop).

The sense of urgency varies, with more vulnerable communities and resources taking higher priority (Juneau workshop). The spatial scale is NPLCC-wide, but is focused on the areas where traditional foods, cultural resources, and natural resources are located (Juneau workshop, Arcata workshop). These include coastal areas and communities and freshwater streams and rivers, particularly harvest areas:

> *…We know that we used to dig for shellfish in an area. And now we are told that we can't, so testing around those areas. How and why they should mitigate things?… (Southcentral and Southeast Alaska Marine).*

> *The important thing for us is knowing whether those species are going to be viable and healthy in the future. Of course it differs by geographic area. I think a lot of the questions we get are: how are the fish in my area going to do… (Columbia River Basin Freshwater).*

The temporal scale extends from the Pleistocene and into the future (Juneau workshop, Arcata workshop). Monitoring for algal blooms that affect traditional food sources should begin now and long-term monitoring should be used to track changes in ocean acidification and paralytic shellfish poisoning that will affect shellfish (Juneau workshop).

Potential partners include Tribes, Alaska Natives, First Nations, Sealaska, and a range of international indigenous entities such as the Indigenous Environmental Network and the International Indian Treaty Council. For resources susceptible to ocean acidification and paralytic shellfish poisoning, potential partners also include commercial industry and Integrated Ocean Observing Systems (IOOS).

Produce data and research that enables decision makers to work together to address climate change effects

Project participants suggested producing data and research that assists the "highest level agency staff in understanding how to work together" (Juneau workshop). Collaboration at the highest levels supports field work and studies to integrate traditional knowledge and information on the impacts to cultural and natural resources such as traditional foods (Juneau workshop). By increasing the number of opportunities for productive and regular collaboration and trust-building, it also strengthens the Government-to-Government relationship between federally recognized tribes and the U.S. government (Lynn 2012, Lynn and Zakai 2012). Participants also suggested enabling easy access of data, studies, and research from science organizations (e.g., NOAA) to other agencies, tribes, and indigenous entities (Arcata workshop). Easy access would provide key information on the health of species and ecosystems, as well as inform consumption and recreation decisions (Arcata workshop).

Overall, connecting data and research at multiple levels facilitates the socio-ecostability of cultures and is a source of guidance for indigenous communities (Southcentral and Southeast Alaska Marine, Juneau workshop). For example:

> *We need to know how to include climate change information into our Way of Life and bringing it home for us about: ―here is what is going to happen."…Connecting it to our Way of Life so that we can adapt and plan (Southcentral and Southeast Alaska Marine).*

Improved collaboration between decision makers would address four concerns identified during the Juneau workshop:

- Tribes are unable to determine which meetings or policies to address.
- Decision makers are scattered in addressing consultations and impacts to culture.
- Decision makers struggle to inform tribes on issues.
- There is a lack of knowledge about when gathering is appropriate.

In terms of the sense of urgency for this activity, climate change is occurring fairly rapidly and the information should be available before decisions are made or plans are created that affect Tribes, Alaska Natives, First Nations, and other indigenous communities (Juneau workshop, Arcata workshop). Partners and ongoing efforts include the Southeast Alaska Conservation Council (SEACC), the Indigenous Environmental Network, and the International Indian Treaty Council.

V. Activity Areas for Freshwater Ecosystems and Habitats

The most frequently discussed freshwater ecosystems were the rivers and streams of the NPLCC region, with a small emphasis on larger rivers and rivers flowing into highly productive or culturally significant nearshore coastal areas. While several science and decision-support activities were identified for freshwater ecosystems, project participants working in the region‟s freshwater ecosystems emphasized improving the sensor and monitoring network, and the vulnerability assessments, prioritization tools, and other capacity-building and decision-support activities that provide actionable level information and enable action on-the-ground. In Alaska and British Columbia, there was also frequent discussion of the effects of climate change and related stressors on hydropower and hydropower infrastructure.

The primary challenges identified by project participants working in freshwater ecosystems are a lack of funding and other capacity, addressing and incorporating uncertainty, a lack of coordination within and between agencies, a lack of data specific to a region or research question, and a lack of actionable level information:

> *Limited capacity to research climate change questions, including modeling and monitoring efforts. Capacity = funding, people, infrastructure (Survey Respondent 58).*
>
> *The biggest challenge is the uncertainty associated with how climate change will affect various ecosystems and what the appropriate response is (Survey Respondent 56).*
>
> *Lack of coordination between institutions and work groups working on climate change. Lack of policy direction for implementing the integration of climate change into work (Survey Respondent 38).*
>
> *In British Columbia, there are many limitations in our knowledge about the hydrological impacts of climate change across different geophysical regions (Survey Respondent 12).*
>
> *One of the biggest challenges our local (field staff) planners face is getting good, solid, accurate, and timely information for the natural resource concerns they are addressing. We don't always have the information we need to plan out approaches to natural resource conservation and therefore we often make our best professional judgments about what we should be doing on the ground (Survey Respondent 10).*

The science and decision-support opportunities identified by project participants for freshwater ecosystems and habitats are captured in a single activity area:

1. Increase the resiliency of the hydrologic regime to climate change and other stressors

Within an activity area, several specific activities requested by project participants are described. The description includes information on how many project participants identified the activity and the climate change-related challenges associated with pursuing the activity. To provide information to the NPLCC about when, where, and under what circumstances support is requested, participant evaluations of the activity across the four evaluation criteria are synthesized:

- *Decision-relevance* indicates which decisions the activity would help inform or guide.
- *Timeline or sense of urgency* indicates when the activity is needed and provides a sense of why and how important, or urgent, it is to pursue the activity.
- *Spatial and temporal scale* identifies the necessary geographic region or spatial coverage for the activity and whether the activity is needed on an annual, seasonal, daily, etc. timescale.
- *Partners and ongoing efforts* identifies the people, partnerships, and organizations that might already have information about the activity or might be well suited to develop it.

1. Increase the resilience of the hydrologic regime to climate change and other stressors

Project participants from nine of thirteen web-based focus groups, all three workshops, and several survey respondents identified the resiliency of the hydrologic regime to climate change and other stressors as an activity area for the NPLCC region.

Specific activities are:

- Develop and implement a climate-smart sensor and monitoring network
- Model freshwater duration, temperature, and flow across the landscape
- Monitor and evaluate water quality
- Assess the integrated environmental impacts of climate change, hydropower and associated hydropower infrastructure
- Promote capacity-building and decision-support for freshwater ecosystems and habitats

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	✓
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	✓
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	✓
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	✓
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

Develop and implement a climate-smart sensor and monitoring network

The request for a climate-smart sensor and monitoring network informed by the multi-disciplinary needs of those working in the region was cited in most web-based focus groups and was also a topic of discussion during all three workshops. The request was made most repeatedly by project participants in Alaska and British Columbia, followed by those working in freshwater systems elsewhere in the NPLCC.

Workshop participants identified two types of decision-relevance for gathering baseline sensor data in a climate-smart way. The first is prioritizing management actions, including restoration, regulation, protection, and monitoring (identifying event probabilities, process linkages, sensitive constituents, measures, seasons, locations, etc.). As additional data is gathered and analyzed, understanding of local and regional patterns and process linkages would improve, and would inform adaptive management decisions, the second type of decision-relevance. Web-based focus group participants echoed the importance of monitoring for adaptive management, saying *[monitoring is] not glamorous, [it is the] first to get cut, [it is] hard to fund but it is essential in doing* *adaptive management. I would love to see the NPLCC move forward on that (California Current Marine #2).*

The sense of urgency for developing this data is high because, as workshop participants stated, this information is fundamental to developing comprehensive information about climate impacts in freshwater ecosystems, current networks are demonstrably insufficient for evaluating climate sensitivity or for making projections, and it takes at least thirty years by convention to generate continuous, high-quality datasets useful for evaluating trends (Portland workshop). Web-based focus group participants reflected this sense of urgency stating *monitoring is critical…[we need] monitoring networks that let us continue to observe these rates and look at the projections of climate (California Current Marine #2).*

The common suggestion was that the NPLCC could provide a framework or location for uniform data collection; for example, a data collection and monitoring plan for the region or assistance making existing data more available:

> *To ensure that NPLCC efforts with regard to monitoring are as effective and efficient as possible, I highly recommend a focused and parallel effort to develop a strategic monitoring strategy. There are a number of mixed-scale monitoring efforts we could learn from, as well as wise people with good and bad experiences putting together complex monitoring programs who could help advise development of a monitoring strategy for the NPLCC. One of the ways to ensure that monitoring remains hard to fund is to spend a lot of effort on it, and then not be able to answer the most critical questions (California Current Marine #1, WA/OR/CA Coastal Ranges and Drainages Freshwater, Portland workshop).*
>
> The NPLCC should develop a strategic plan to prioritize and execute improved data collection on precipitation and discharge to better parameterize scalable hydrologic models along watershed lines (Juneau workshop).
>
> *The NPLCC could, through its network, identify top concerns for what would then pertain to networks and preserving networks that are most critical. The challenge is that there are so many issues and so many different lists that are important. How can we identify the top 3-5? (California Current Marine #2)*
>
> *One is the idea of partnerships…There are already partnerships with monitoring…how [would] a partnership with the NPLCC…be helpful in monitoring or [to] augment areas that are important to monitor? (California Current Marine #2).*
>
> *There is little collaboration across research projects which means that there are holes in the research. Data is not collected in a useful framework. Data is already limited, and also unorganized. There is a need for information on multiple types of areas such as multiple types of watersheds (Alaska and British Columbia Coast Freshwater).*

Project participants noted that a strategic approach to monitoring would address key challenges associated with gathering and using hydrologic data in their work and would advance their ability to address current and potential future climate change effects. Key challenges fall into three categories, each of which is discussed in turn:

- Insufficient climate and weather stations, cited particularly in Alaska
- Inadequate streamflow gauges and related information
- Inadequate water temperature information

Climate and weather stations in Alaska are widely dispersed geographically and do not capture the dynamic topography of the coastal region. Funding is already insufficient and is declining further:

> *I don't know how to address the weather station data gap, but that is a huge one in Alaska. Most stations are at sea level or valley bottom locations which is problematic when trying to make extrapolations to other areas outside of those locations. It seems like most of the satellite sensors that could be used to develop some sort of indication of climate outside of those locations are also not totally useful up here either. So that is a huge data gap, that there are not many climate stations and there are not that many hydrologic stations either. Some of the projected changes would strongly affect hydrologic, rain-on-snow events, that type of thing. We'll have some problems certainly in figuring out the magnitude of those changes on hydrology without an abundance of monitoring that particular variable at this time (Coastal Temperate Rainforest Ecosystem).*

> *It is hard when you are asking for specifics because there is so much that we don't have, so much fundamental information. With declining budgets – I hate that catch phrase – they have stopped funding incrementally the hydrologic gauging stations in the Alaska region. Whether it's the weather stations that don't cover the range of areas, we are actively having to choose what we stop doing. This is something happening across the country (Coastal Temperate Rainforest Ecosystem).*

In addition to minimal climate and weather stations to measure precipitation, there are too few stream gauges to measure runoff and other hydrologic data in Alaska, British Columbia, and the coastal freshwater drainages of Washington, Oregon, and California (Box 6, p. 72). There is also a disconnect between where data is available and where it is needed:

> *There are few stream gauges currently in place and those that are in place are threatened by budget cut backs which are cutting out what gauges there are. There is very little historic data on streams. There is only sparse data then on snow and glacier runoff (Alaska and British Columbia Coast Freshwater).*

> *It should be reiterated that physical drivers and changes are not well understood, both spatially and temporally – e.g., disconnect between USGS gauging, precipitation records, and the watersheds where information is really needed. We should be cataloging what we have and starting from there (Alaska and British Columbia Coast Freshwater).*

> *…speaking about the management of the Klamath Basin in general, I think the biggest concern about uncertainty especially related to climate change is water quantity related*

to snowpack and things like that. The water availability is already a difficult issue to manage in the basin (Lowlands, Prairies, and Other Non-forested Ecosystems).

However, some participants did indicate that basic data was improving in the Willamette Valley and parts of the Klamath Basin, but the coastal drainages of Washington, Oregon, and California remain data-poor, particularly in comparison to the Columbia River Basin (Box 6) and marine nearshore and estuarine environments (see Chapter VI.1, p. 89):

> *We still have the problem of data to show that we have a problem and that we need to work on it. Are there impacts that we can see now that we can match with predictions to strengthen the argument? (WA/OR/northern CA Coast Ranges and Drainages Freshwater).*

> *There is a need to downscale predictions to specific watersheds/land areas. There is a need to translate predictions to specific actions on the ground to address these (e.g., what more can be done to restore areas in headwaters already in wilderness areas?) (WA/OR/northern CA Coast Ranges and Drainages Freshwater).*

Similar to the climate and weather stations, the network for monitoring streams is unable to capture the significant topographic variability of the Alaska and British Columbia coastlines:

> *[There is a] lack of hydrologic projections. Very few gauges and dynamic topography. Without information, can't measure streamflow amount, timing, and temperature (Alaska and British Columbia Coast Freshwater).*

> *I would second that – stream gauge data, limited precipitation data and the region is highly variable – more on freshwater input… Again, there are a large number of rivers on the coast of AK that are not gauged so we don't know what they are doing now let alone how they are changing. Even in the Copper River it is hard. It is hard to know. There is also a high variability between areas (Southcentral and Southeast Alaska Marine).*

Box 6. Contrasting Data Availability in the Columbia River Basin and Coastal Freshwater Drainages

Project participants noted the lack of data in the coastal freshwater drainages of Washington, Oregon, and California contrasts the apparent availability of data in the Columbia River Basin:

> *There is no inventory of forest service lands or ownership to focus projects which creates hurdles. Much of the work has focused on the Columbia River Basin instead of the coast. There are significant differences between the coastal areas and the Columbia River Basin (WA/OR/northern CA Coast Ranges and Drainages Freshwater)*

One web-based focus group participant suggested the discrepancy in data availability may be due to funding from the Bonneville Power Authority in the Columbia River Basin (WA/OR/northern CA Coast Ranges and Drainages Freshwater). To improve data availability in the coastal freshwater drainages, the University of Washington Climate Impacts Group has data available and can assist with downloading data.

Researchers noted concerns with interpolating streamflow, water temperature, and other hydrologic data from nearby stations or using another station‟s data as an estimate for an ungauged stream:

> *… a huge challenge here in BC in dealing with climate change is maintaining and conserving aquatic-based natural resources especially fish is the fact that we have such a bad monitoring network around hydrometric requirements. [We have] minimal hydrometric data for most watersheds that we currently work on. [We] either have to synthesize or use surrogates from nearby watersheds to dictate what the science around flow and fish habitat relationships is and what we can expect in future flows especially during base flow from early July through end of October. We see an increasing frequency of drought and significant impacts on aquatic resources in these communities that depend on these resources. In most watersheds we have no science-based hydrometric data both on flows and water temperatures on which to make adaptive decisions. So that's from my perspective having worked in the industry for the last 40 years – that's one of the key sets of challenges we face with climate change (Puget Sound and Georgia Basin Freshwater).*

Water temperature monitoring is also a challenge due to poor spatial coverage across the landscape, insufficient temporal data, and limited funding:

> *―[There is an] insufficient period of record and spatially patchy water temperature monitoring data to accurately model/predict/characterize expected trends in stream temperature or assess relative vulnerabilities of surface waters associated with climate change" (Survey Respondent 7).*

> *We work on the Kitwanga River where there is a run of genetically unique sockeye salmon spawning in the lake. Like most of the region, there is no money for long-term monitoring of the salmon and their habitat such as water temperature, which is critical for their survival. Most monitoring is through private projects. It is a struggle to do annual temperature monitoring (Pacific Coast and Nass Ranges Freshwater).*

In terms of spatial scale, these data should be available at the level of human impacts, relative to sensitive resources, and particular to types of water bodies (e.g., lakes, reservoirs, streams, groundwater). The spatial scale was further categorized into intensive and extensive spatial sensor networks. The intensive spatial sensor network would be more focused on local issues and questions, while the extensive network would include regionally coherent climate signals and other sensor information that can not be gathered locally.

In terms of temporal scale, continuous, multi-year data streams are requested, as is multi-decadal data. Workshop participants noted that long-term monitoring does not fit with current funding cycles because funding is typically available for short periods of time (one to three years). However, the Babine Watershed Monitoring Trust has been successful in securing long-term funding for monitoring.

Given the long timeline for generating useful trend information, workshop participants identified a number of collaborative opportunities for coordinating existing data gathering efforts:

- To collate existing data and coordinate on monitoring networks, collaboration between state, federal, and tribal agencies, watershed councils, and lake associations is suggested. Intensively monitored watersheds are an example of an ongoing effort that could serve as a pilot for improved coordination and collaboration.
- Coordination of standard quality assurance and quality control measures, other protocols, and data stewardship would improve collaboration and make existing sensor networks more climate-smart.
- There is an "Agreement on Management of Meteorological Networks in the Province of British Columbia." This public-private data sharing agreement was developed to share meteorological data in British Columbia between British Columbia Hydro and Power Authority, Rio Tinto Alcan Inc., Pacific Climate Impacts Consortium, and the BC Ministries of Environment, Transportation and Infrastructure, Forests and Range, and Agriculture and Lands.

Lastly, the Canadian Council of Ministers of Environment produced *Selected Tools to Evaluate Water Monitoring Networks for Climate Change Adaptation* (PDF, 1.31 MB), a "reference document for non-specialist water managers and climate change adaptation planners…to help Canadian federal, provincial and territorial governments determine the suitability of their water monitoring networks to provide the data needed to plan for and to adapt to a changing climate"

Model freshwater duration, temperature, and flow across the landscape

In discussions of freshwater duration, temperature, and flow, project participants emphasized pursuing projects that identify and model potential and future hydrologic change as well as those that connect the freshwater system with terrestrial and marine systems:

> *We live in a rainforest driven ecologically, economically, and culturally by the input of water – annually, seasonally, and varying amounts. Varying widely across the archipelago – modeling the possible scenario changes that could occur over time is critical (Portland workshop).*
>
> *I see the NPLCC as tackling what no one else wants to of freshwater and near shore and all that: transition from terrestrial to marine – hugely productive, hugely challenging, no one else is tackling it and it would be good for the LCC. I see this group as really appropriately tackling all of that (Southcentral and Southeast Alaska Marine).*

Improved information about the movement of water across the landscape and ecological responses to hydrologic change would inform decisions about commercial and Subsistence harvest of resources, recreation, tourism, human health, and if and where the best places are to develop "fish-friendly" hydropower. It would also inform adaptation planning (e.g., where to invest federal and private partner funds to restore watersheds for salmon or other objectives), wetland functional assessments and potential shifts in future functioning, decisions about which gauging stations to keep or add, identification of indicator species (see Chapter VIII.3, p. 158 for more information), and would help identify existing ecohydrological thresholds. Research on potential future hydrologic change is of high urgency to conduct, particularly information on freshwater flow. Project participants suggested beginning now because multiple years of research effort will be needed before the results can be applied on the landscape and to decisions. Temporally, models and projections should provide information over historical, short-term (10-30 years) and long-term (30+ years and preferably at least 50 years) time periods.

Specific modeling suggested by project participants includes:

- Downscaled models and forecasts of snowmelt, glacier melt, and ice melt (Juneau workshop)
- Models linking hydrologic changes to species and habitat responses from watershed headwaters to nearshore areas (Juneau workshop).

Spatially, the hydrologic models and projections cited should range ideally from the patch to the watershed scale across the entire NPLCC. The approach should be systematic at the subregional scale, for example focusing on southeast Alaska. Water temperature models were also suggested:

> *NPLCC should work on temperature models at appropriate (smaller scale) levels… such a model would be useful to identify relative vulnerability or resilience of streams within subwatersheds with respect to climate change… (WA/OR/CA Coastal Ranges and Drainages Freshwater)*
>
> *—[Need] funding for additional water temperature monitoring data collection to accurately model/predict/characterize expected trends in stream temperature and assess relative vulnerabilities of surface waters associated with climate change" (Survey Respondent 50).*

As mentioned in the invasive species chapter (see Chapter IX, p. 166), nearshore temperature and freshwater input *are the core in the niche models for the Alaska nearshore models for marine invasive species (Southcentral and Southeast Alaska).* These should be included in models in order to inform decisions about where to monitor and mitigate for potential marine invasive species. In general, water temperature models should be *appropriately scaled to inform federal land management decisions* (WA/OR/CA Coastal Ranges and Drainages Freshwater) and should focus on identifying nearshore coastal areas susceptible to invasion and on the Coast Ranges of Washington, Oregon, and California.

Juneau workshop participants requested additional information on freshwater flow and duration on the landscape, including snowpack, glacier melt, soil water storage, stream water depth, nutrient retention and delivery, and freshwater delivery to estuarine and nearshore areas (Juneau workshop). These include improved watershed Q and flow models that incorporate soil and vegetation typing to produce better discharge and flux projections (Juneau workshop). Within the next five years, improved watershed Q and flow models are requested to translate General Circulation Model (GCM) and downscaled model outputs into watershed models for predictions of specific Q parameters, e.g. mean and flood frequency. Information on nutrient delivery and retention, freshwater flow, and freshwater duration is requested annually. In general, spatially explicit estimates of changes in hydrology, at the finest scale possible, are ideal. Acknowledging the difficulty of obtaining fine-scale, spatially explicit information for every variable, the following spatial scales are suggested:

- Information on nutrient retention and delivery at the watershed scale

- Information on freshwater flow ranging from the plot to watershed scale
- Information on freshwater duration focused on the watershed but extending from the plot-level to the region
- For information to input into watershed Q and flow models, focus on watershed to mesoscale processes.

Given the mismatch between the hydrologic regime and salmon life history and increasing rates of glacial melt, downscaled hydrologic and species/habitat response models as well as models which "bracket" the range of possibilities over the next few decades are a short-term request (Juneau workshop). The ability to project hydrologic conditions also supports improved understanding of process and function in the ecosystem including nutrient cycling, food webs, and species abundance and distribution. This includes understanding the impacts of retreating glaciers (e.g., altered streamflow and river discharge) on salmon cycles, fish migration, riverbank erosion, nutrient cycles, and productivity (Juneau workshop). It also includes monitoring and management of species such as salmonids and blacktail deer:

> *Alaska makes for an interesting case due to the topography because snowfall differs at different elevations. This can have significant impacts on wildlife. An example of this is the black tail deer – the ability to predict snow accumulation affects ability to manage blacktail deer. When snow falls at lower elevations the deer are forced into lower grazing areas (as low as the beach) and if it falls too low deer can starve as their food source is taken away (Alaska and British Columbia Coast Freshwater).*

> *…There is a delicate balance with the Kitwanga run. [The lake is] warm and shallow in summer and very productive, but [if it is] too warm juveniles are not feeding because they are in an oxygen and temperature refuge that lacks food (Pacific Coast and Nass Ranges Freshwater).*

Projections of snowfall in the Klamath Basin *would be great… because we would be better able to predict how long water would last and how much might end up in the river (Lowlands, Prairies, and Other Non-forested Ecosystems).* In addition, an improved understanding of groundwater is requested because groundwater provides late-season flow in the watershed:

> *We also know that ground water and the sources of rivers are the key sources [for] salmon spawning. We should focus on factors such as groundwater input; where it occurs in a system and how it impacts it. That way we get a better understanding of the systems. Mapping groundwater areas and determining contribution of groundwater in late summer when river temperatures are high and flows are low (Pacific Coast and Nass Ranges Freshwater).*

Participants further suggested that in order to focus on and better understand marine nearshore, marine offshore, estuarine, and freshwater connections, basic hydrologic data on freshwater input in the tidal riverine subsystems and estuarine-marine interfaces (stream gauge data including seasonal and peak river discharge, more precipitation data, changes to flow and nutrient composition in glacial streams; see Figure 3, p. 88 for more information on tidal riverine, estuarine, and marine interfaces) as well as resulting changes in marine nearshore circulation, biological communities (invasive species, life cycles &

histories of ESA and other species), nutrient cycles that form the base of the aquatic food web (nitrate, iron, silicate, phosphate), and food web interactions (forage fishes and seabirds) should be gathered:

> *Estuary changes – connecting freshwater and nearshore. From a fish and wildlife perspective in southeast Alaska, most of the resources we are directly responsible for we are focused on nearshore and intertidal aspects [and the] life cycle of different species. I have very little understanding of how these estuaries are going to change in terms of freshwater input and the types of currents changing and how that will change the character of estuaries and the relationship between the marine water side of that and the intertidal areas and the areas directly adjacent to that… (Southcentral and Southeast Alaska Marine).*
>
> *… I would broaden it to say that freshwater input and nearshore water temperature because those two are the core features in the niche models for the AK near shore models for marine invasive species. I see the NPLCC being (marine waters) the corridor in which these invasives will ‗march on up' – LCC waters are the corridor for marine invasives to be travelling. There is so much coast line but it is important to know where we should focus on new invasions (Southcentral and Southeast Alaska Marine).*
>
> *I am thinking a little farther offshore in terms of data for sea birds and the sea food web. Forage fishes. Food web interactions for seabirds farther offshore and impacts on forage fishes (Southcentral and Southeast Alaska Marine).*

The suggestions outlined in this section would address the challenges described in the previous section (e.g., insufficient climate and weather stations, inadequate streamflow gauges, inadequate water temperature information) as well as several others:

> *In British Columbia, there are many limitations in our knowledge about the hydrological impacts of climate change across different geophysical regions (Puget Sound and Georgia Basin Freshwater).*
>
> *Another thing: glacial monitoring. There is not a lot in this area. One thing that could help us would be to tap into predictive monitoring around stream temperatures, oxygen, etc… (Pacific Coast and Nass Ranges Freshwater).*
>
> *…As you are melting more glaciers in the summer time and shifting towards more freshwater input in the summer you are perturbing stratification offshore that has impacts on nutrient cycles offshore. It is a harder thing to get a handle on than you might think… (Southcentral and Southeast Alaska Marine).*

Many partners and ongoing efforts were identified for this activity. For specific assistance with modeling:

- Dan Isaak with the U.S. Forest Service Air, Water, and Aquatic Environments Science Program is working on a temperature model for the Columbia River Basin and may be able to assist with models for other subregions of the NPLCC.

- Jim Hatten (U.S. Geological Survey, Western Fisheries Research Center) was suggested for assistance with aquatic system modeling and has expertise in cell-based (GIS) predictive modeling, remote sensing, and landscape ecology.

For assistance with groundwater and surface water:

- The Canadian Council of Ministers of Environment produced a *Review and Assessment of Canadian Groundwater Resources, Management, Current Research Mechanisms and Priorities* (PDF, 83 KB) that includes a brief discussion of climate change effects on groundwater resources.
- Marshall Gannett (U.S. Geological Survey, Oregon Water Science Center) focuses on characterization and modeling of groundwater and surface water (e.g., a basin-scale study. Current projects include "characterizing and modeling the regional ground-water system in the upper Klamath Basin in Oregon and California, and modeling the groundwater response to climate change in the upper Deschutes Basin in Oregon."
- Lori Flint (U.S. Geological Survey) is a Research Hydrologist and suggested contact for information on integrated modeling of groundwater, surficial flows, and climate effects.
- Brian Richter (The Nature Conservancy) was suggested as a potential partner on environmental streamflows.
- Cindi Barton (U.S. Geological Survey) is Director of the Washington Water Science Center and was suggested as a general contact for information on watersheds.
- In California:

  "Dave Herbst initiated a study of 12 subwatersheds in 2010 to assess relative vulnerabilities of surface waters in the Sierra-Nevada Range associated with climate change. I have loaded all available water temperature monitoring data collected on National Forests in California to date into NRIS AqS - our corporate database" (Survey Respondent 7). Hyperlink added.

For specific assistance with glaciers and glaciated systems:

- Bill Bidlake (U.S. Geological Survey, Washington Water Science Center) is a suggested contact for Pacific Northwest glaciology.
- Shad O'Neel (U.S. Geological Survey) specializes in glacier-climate interactions and sea level rise, small glaciers, glacier-generated seismicity, and photogrammetry and was suggested as a potential partner on quantitative modeling of glacier mass.
- Roman Motyka (University of Alaska Southeast) was a suggested contact for information on Alaska glaciers. Research includes tidewater glacier dynamics with a focus on southeast Alaska, thinning of the Mendenhall Glacier, uplift, isostatic rebound and plate tectonics in southeast Alaska, the contribution of Alaska glaciers to global sea level rise, and developing ice-load models for Glacier Bay and the Yakutat Icefield in southeast Alaska.
- Scott Rupp (University of Alaska Fairbanks) was suggested as a potential partner on climate modeling and associated effects on glaciers and watersheds. Other research interests include ecosystem and landscape ecology, with an emphasis on "secondary succession, regeneration, and disturbance dynamics in subarctic and boreal forest."

- Eran Hood (University of Alaska Southeast) was suggested as a potential partner for information on the effects of glaciers on the freshwater and marine environment in southeast Alaska. General research interests include watershed-scale biogeochemistry, nutrient cycling in aquatic systems, alpine hydrology, and snow hydrology and snow chemistry.
- Alexander Milner (University of Birmingham) was suggested as a contact for information on aquatic ecology and Alaskan hydrologic regimes, including a study in Glacier Bay that is the "longest continual study of stream succession and development within a primary successional framework" and broader investigation of "how water sources are changing in glacially influenced river systems with climate change and how these changes alter ecological structure and function."
- Stephen Gray (U.S. Geological Survey, Alaska Climate Science Center) is Director of the Alaska Climate Science Center and was a suggested contact for information on the effects of glacier melt in ecosystems.
- Sanjay Pyare (University of Alaska Southeast) was suggested as a potential partner for information on glacial effects on sustainable communities. General research interests include GIS-supported landscape assessments, ground-truthing GIS and remotely sensed resources, landscape connectivity, habitat modeling and animal dispersal and movement, aquatic-terrestrial-marine interactions, hands-on and experiential education, and supporting the information needs of resource managers.

For specific assistance with soil hydrology and general hydrology, there are soil hydrology and watershed hydrology modeling efforts in the Pacific Northwest, a hydrologic observatory in Juneau (contact Dave D‟Amore for more information), and a Colorado State collaboration on wetland productivity.

For assistance with climate change adaptation approaches, the Tulalip Tribes are using gabions (engineered structures used to store solid materials such as soil) in mountains to store snow and are using perched constructed wetlands to slow down water and capture organics and sediments.

Other potential partners include federal agencies such as the USGS and U.S. Forest Service, the Climate Science Centers, the University of Alaska (Fairbanks and Southeast), power companies, and weather monitors.

Monitor and evaluate water quality

Water quality was discussed by workshop participants in Juneau and Arcata, but was not a specific topic in the web-based focus groups. Workshop participants isolated the nearshore environment, contaminants, and harmful algal blooms as the key topics to consider for water quality monitoring and evaluation in the NPLCC region:

- A nearshore water quality system is suggested. The nearshore is a large gap in current data (Juneau workshop).
- Long-term monitoring of contamination is requested, particularly direct delivery from India and China (mercury) via the grasshopper effect – tropical and sub-tropical contaminants that are up in the air, then cool, and are deposited in the north. Sound contamination should also be addressed (Juneau workshop).
- Evaluate harmful algal blooms. This is important because of the toxins to shellfish and increase in occurrence (Juneau workshop). *Note: harmful algal blooms are also discussed in Chapter VI.2.*

- Bioaccumulation and biomass testing, as well as alerts, are requested (Arcata workshop)

In their white paper on climate change and research considerations, the California Coastal Commission also suggests assessment of current water quality Best Management Practices (BMPs) to determine needed design changes and evaluate efficacy given varying implementation scenarios:

> —*...Water Quality: Assessment of all currently applied BMPs to identify design changes needed to address future hydraulic and hydrologic conditions; Assessment of the impacts of climate change on the amounts of pollutants that will be transported to coastal waters under various scenarios of BMP implementation…" (Survey Respondent 33; also see p. 5 California Coastal Commission, 2008)*

This information would provide baseline data on the health of organisms and ecosystems that would inform efforts to protect public and ecosystem health, sustain recreational and subsistence harvest, and address the cumulative effects of warming water, contamination, and acidification on marine and aquatic organisms. The nearshore is utilized by organisms at various lifestages, even though its importance to marine ecosystems is largely unknown though assumed to be important. The nearshore water quality monitoring could begin as a pilot study in nearshore areas of the NPLCC region already affected by potential climate change effects (e.g., harmful algal blooms, hypoxia, ocean acidification), and the findings could guide future work and benefit other nearshore areas.

Information is requested NPLCC-wide, but focused on the nearshore area and long-lived food items utilizing those areas (e.g., shellfish, fish, gull eggs, mammals, seals, whales, and halibut). The nearshore is the critical land-sea transition area and little comprehensive data is currently available. The temporal scale is long-term and would ideally be ongoing. Data may need to be refined to seasonal or monthly time periods, but year-round monitoring is preferred. Investigations of harmful algal blooms should be conducted when it warms right after winter. Long-term monitoring of contamination could be initiated in the next year or two, but would be needed prior to decisions, planning, and implementation activities.

Assistance with a nearshore water quality monitoring program could be provided by Ocean Observing Systems (IOOS; e.g., NANOOS), Tribes, and local and state governments. For harmful algal blooms, potential partners include citizen science monitoring efforts, local cities, communities, and Tribes. Any available training would support their own monitoring efforts. Sealaska and commercial industry partnerships may be able to assist as well.

A range of international, regional, state, and local partners are available for advancing long-term monitoring of contamination in nearshore areas:

- *International:* The Indigenous Environmental Network (specifically Reducing Emissions from Deforestation and Forest Degradation information), International Indian Treaty Council, United Nations Declaration on the Rights of Indigenous Peoples (PDF, 165 KB), and the Indigenous Peoples Global Summit on Climate Change (2009; links to report on summit, PDF, ~870 KB).
- *Regional:* The Northwest Association of Networked Ocean Observing Systems (NANOOS) and ocean observing systems in general. Information on ocean indicators is available in the book "Breaking Ice: Renewable Resource and Ocean Management in the Canadian North" (PDF, 3.28 MB).

- *State:* California Department of Fish and Game, California Regional Water Boards, Washington State Department of Ecology, and state health departments.
- *Local:* The Anchorage Declaration, county health departments, and the Humboldt Bay Harbor, Recreation, and Conservation District.

Assess the integrated environmental impacts of climate change, hydropower, and associated hydropower infrastructure

Web-based focus group participants in British Columbia and Alaska requested improved hydrologic data and projections in light of an increasing number of hydropower projects in the region and high uncertainty about how climate change may affect watershed hydrology with increased hydropower generation. While participants in Washington, Oregon, and California did discuss the usefulness of research on climate change and hydropower, it was cited much less frequently and was not termed a priority by most participants:

> *…So looking out, hydrological outlooks are directly related for us – We need specific hydrological information in order to ask and answer questions about climate change and hydropower (Southcentral and Southeast Alaska Marine).*
>
> *There are some who are interested in implementing small hydro projects. It is however very difficult to plan for hydro when future water reserves are not known. This pertains a lot to the design of and decisions around fish passages (Alaska and British Columbia Coast Freshwater).*
>
> *I think that probably the question that's coming up for us right now that's most relevant is in looking at some of the longer-term kinds of actions, for example hydroelectric facilities. There are between 25 and 40 new or revisiting hydroelectric facilities [that] are being reviewed in southeast Alaska these days, with potential licenses up to fifty years and renewable. We need to figure out our responsibility – the biggest one is trying to reserve enough water for fish – related to the water bodies that are affected. So it's a hydrological need over the long-term looking at quantity and seasonal flow of water (Coastal Temperate Rainforest Ecosystem).*

Many of the proposed and new hydropower projects are planned for upstream areas of the watershed where there is currently little infrastructure. Workshop participants emphasized the importance of understanding the integrated ecological effects of added infrastructure, the resulting hydropower generation, and the overarching climate change impacts in these upstream areas:

> *We have more than a 1,000 applications for run of the river hydro. This will have a huge impact on streams and rivers and have not given much thought to what this is going to mean. Many of them are in very remote areas which means that they will have to put in infrastructure into remote areas which will have an impact on the area. [We] must also take this into consideration (Pacific Coast and Nass Ranges Freshwater).*

> *It is important to know things such as the degree to which structures affect bed flow and sediment and water quality in head ponds of dams (Alaska and British Columbia Coast Freshwater).*

However, it is the climate change and hydrologic information that is currently lacking that is critical for a thorough and credible review and assessment of potential environmental impacts. Without this hydrologic information, a proper review of potential impacts of the hydropower projects will not be possible:

> *…We can't legitimately review those [alternative energy projects such as hydropower] without having a pretty good handle on what climate change will mean to the hydrological cycle. For any type of development that demands water, even mining… (Southcentral and Southeast Alaska Marine).*

For example, the construction and use of hydropower facilities would affect *the design of and decisions around fish passages (Alaska and British Columbia Coast Freshwater).*

The spatial scale is focused on Alaska and British Columbia in the watersheds where hydropower projects are proposed, and could be expanded to other areas in the NPLCC if they begin to face similar challenges. The temporal scale would extend at least fifty years into the future, because licenses are available for up to *up to fifty years and renewable (Coastal Temperate Rainforest Ecosystem).*

Potential partners include the U.S. Fish and Wildlife Service office in Juneau, the University of British Columbia Institute for Resources, Environment, and Sustainability, the HydroNet program at the Natural Sciences and Engineering Research Council of Canada‟s, Clean Energy BC, and the U.S. Forest Service Pacific Northwest Research Station. HydroNet is "a national research network aimed at promoting sustainable hydropower and healthy aquatic ecosystems in Canada" that focuses on two research themes: ecosystemic analysis of productive capacity of fish habitats in rivers and modeling of fish-habitat interactions in the context of hydropower. Clean Energy BC recently released a draft Integrated Resource Plan, which includes information on climate change effects on BC hydrology (PDF 8.43 MB) and assessments of hydropower resource options (see Chapter 3 [PDF 992 KB] and related Appendices).

Promote capacity-building and decision-support for freshwater ecosystems and habitats

Project participants from the Pacific Coast and Nass Ranges Freshwater and British Columbia Coast Marine web-based focus groups, the Arcata workshop, and Survey Respondent 39 suggested several capacity-building and decision-support activities to enhance the resilience of freshwater ecosystems to climate change and advance efforts to manage freshwater habitats in light of climate change effects. Capacity-building activities include guidance and tangible examples of progress:

> *…[We need] practical, on-the-ground Best Management Practices on incorporating climate change into stream restoration and conservation (British Columbia Coast Marine).*

> *The Gitanyow have a comprehensive land use plan for their traditional territory now. In that plan we have put in a lot of extra protection in for water…We picked out the biggest*

flood plain ecosystem in the territory, the Hanna and Tintina Creek watersheds, which is also where 80% of the Nass sockeye spawn…Through the land use planning process, in which government and the forest industry participated, we made the Hanna and Tintina watersheds a protected area. The process for legally establishing Hanna and Tintina Creeks as a protected area is now underway…It's amazing how well that land use plan has already helped. For example, it's helped with the NW transmission line. When that project was in the proposal stage, they wanted to put it through the middle of the floodplain in the Hanna and Tintina watersheds. Because we had this land use plan in place, we had a much stronger argument to get BC Hydro to pick an alternate route for the line and so they did. They moved the line completely outside the Hanna and Tintina watersheds to an area that we think has much less impact. I see comprehensive land use plans as an important way to adapt (Pacific Coast and Nass Ranges Freshwater).

Decision-support activities include addressing the lack of tools to identify high-priority conservation areas and vulnerability assessments:

> *―[There is a] lack of tools [to] help us identify high priority areas for conservation in the Pacific Northwest. Hopefully funding will continue for the Washington Wildlife Habitat Connectivity Working Group, but the focus of this group is terrestrial species. We need a comprehensive tool for aquatic habitats too…" (Survey Respondent 39).*

> Vulnerability assessments would help determine which species are susceptible to change due to changes in fog and snow (Arcata workshop). The status of species should be determined by data collected under historic and current climates, then projected into the future using available information on future climates (Arcata workshop).

Finally, to respond to significant losses of wetlands, one web-based focus group participant supported specific changes to land use including increasing buffer zones for streams and wetland enhancement:

> *We should have larger buffer zones for streams…shading. That way the temperature change will not be as large. We should also enhance and build as many wetlands as possible – already loss of 50% of Canada's wetlands… (Pacific Coast and Nass Ranges Freshwater).*

Two tools to build capacity and provide decision-support were suggested:

- The National Compendium on Water Resource Adaptation to Climate Change is "an online tool that provides access to information from a variety of sources about climate change adaptation and water. The goal of the compendium is to "provide relevant information to users to help overcome knowledge barriers related to climate change adaptation and water."
- A *Compendium of Climate Change Vulnerability Assessment Tools for Watersheds* will be available in late 2012 from the Canadian Council of Ministers of Environment (CCME). ESSA Technologies worked with CCME to produce the Compendium (synopsis available here), which includes tools relevant to the Canadian context that are "varied and diverse, ranging from indicator based approaches to sophisticated

hydrological models that calculate exposure to flood events under future projections of climate change. They also range from qualitative to quantitative approaches that address a broad range of characteristics of social-ecological systems."

VI. Activity Areas for Coastal Ecosystems and Habitats

Coastal ecosystems and habitats in the NPLCC region covered explicitly in this report are defined as those in the marine nearshore and estuarine environment (MCSDC 2012; Figure 3, p. 88). The most frequently discussed coastal ecosystems and habitats were the region‟s estuaries and tidal wetlands, followed by the coastal habitats utilized by species susceptible to ocean acidification such as shellfish and Pacific salmon. Project participants emphasized projects and activities that provide fundamental or baseline data in these habitats to feed into the maps, visualization models, and decision-support that enable participants to take action to address climate change effects. However, unlike their freshwater counterparts, some participants were overwhelmed by the amount of available information for the marine ecosystem, especially in the California Current region:

> *…There is a lot of information out there that spans entire California Current area and so coordination in type of data collected, funding, adaptation strategies, and outreach is a suggestion (California Current Marine #2)*

> *I struggle with the amount of information that is out there and my ability to absorb it. There is a lot of information out there and I don't have the time to understand the impact. A little too overwhelming (Puget Sound and Georgia Basin Marine).*

Similar to their freshwater counterparts, project participants working in coastal ecosystems requested assistance organizing data and coordinating information exchange (see Chapter V.1, p. 69 for information on freshwater ecosystems):

> *Someplace like a clearing house would be good… NOAA has a librarian who posts the newest information. There is an overwhelmingly large amount of information which makes it difficult. How can you deal with so much information? How to make information more accessible? (California Current Marine #2).*

The primary challenges faced by project participants working in the NPLCC region‟s coastal ecosystems are a lack of funding, the difficulty associated with addressing climate change given existing priorities, political and social barriers, and capacity, a lack of location-specific or actionable level information, and a lack of coordination among agencies:

> *Data collection and monitoring of species is currently being cut back but these are both needed in order to understand the impacts of climate change on our coastal ecosystems and to create a plan for moving forward (Survey Respondent 2).*

> *There needs to be more funding made available to scientific research on the effects of climate change on beach and nearshore environments. Many millions of dollars are spent annually on ecosystem restoration projects and most of these projects have uncertain viability in light of climate change (Survey Respondent 52).*

Challenges include: *Limitations set by the Chapter 3 policies of the Coastal Act. Limitations of local and state government policy… Resistance of the general public to the seriousness of Climate Change (Survey Respondent 35).*

We have a new no sea wall program but we don't know how that is going to work. We require monitoring of all projects but we don't have the staff to review the reports that come in. What are the adaptation strategies to apply and start integrating it into our work? (California Current Marine #2)

Getting climate science information at the scale and resolution that is useful in making local land use decisions; lack of technical capacity to use modeling and mapping tools (Survey Respondent 29).

Lack of examples of what others have done (specific codes addressing SLR for example) and lack of information on impacts specific to this jurisdiction (Survey Respondent 61).

In a recent survey assessment of coastal adaptation needs of nearly 600 coastal professionals working along California‟s coastline, many of the challenges and opportunities identified have also been identified by coastal professionals throughout the NPLCC region. In the California Coastal Adaptation Needs Assessment, the most significant barriers to climate change adaptation planning are insufficient staff resources to analyze relevant information, lack of funding to implement a plan, current pressing issues are all-consuming, and lack of funding to prepare a plan (Finzi Hart et al., 2012, p. 15, Figure 8). More than fifty percent of respondents identified these issues as a "big hurdle," and all but the latter barrier were identified by more than sixty percent of respondents as a "big hurdle" (Finzi Hart et al., 2012, p. 15, Figure 8).

Furthermore, local, state/regional/federal respondents, and elected officials cited the lack of funding to develop and implement an adaptation plan as the primary hurdle, while NGO respondents stated the primary hurdle is insufficient staff resources (the only issue mentioned by at least 60% in the group) (Finzi Hart et al., 2012, p. 16). Insufficient staff resources to analyze relevant information and current pressing issues are all-consuming were also frequently cited challenges in the NPLCC region. The other two barriers were not commonly cited, which may be because we did not ask specifically about adaptation planning. Instead, we asked about challenges and opportunities to incorporate climate change into existing work. Therefore, these barriers may or may not be present throughout the NPLCC region.

The California Coastal Adaptation Needs Assessment concluded that there is a "remarkable readiness among California coastal professionals to address climate change, with both mitigation and adaptation now being a high priority for all respondent groups, and adaptation the higher priority for state/regional/federal, NGO, and private sector respondents" (Finzi Hart et al., 2012, p. 17). Despite this readiness, most coastal professionals are in the early stages of adapting to climate change, an observation that would require further study in the NPLCC region to investigate properly:

...the reality is that about two out of five coastal professionals (41%) are still in the very early stages of trying to understand what the climate change threats are for which they need to develop adaptation strategies, and another two out of five respondents (41%) are

> *just beginning to brainstorm what might be done. A far smaller group (11%) stated they have begun to implement some adaptation options (Finzi Hart et al., 2012, p. 17).*

The authors conclude with thoughts on next steps, including the need for outreach and training on coastal adaptation methods and strategies that was also requested throughout the NPLCC region:

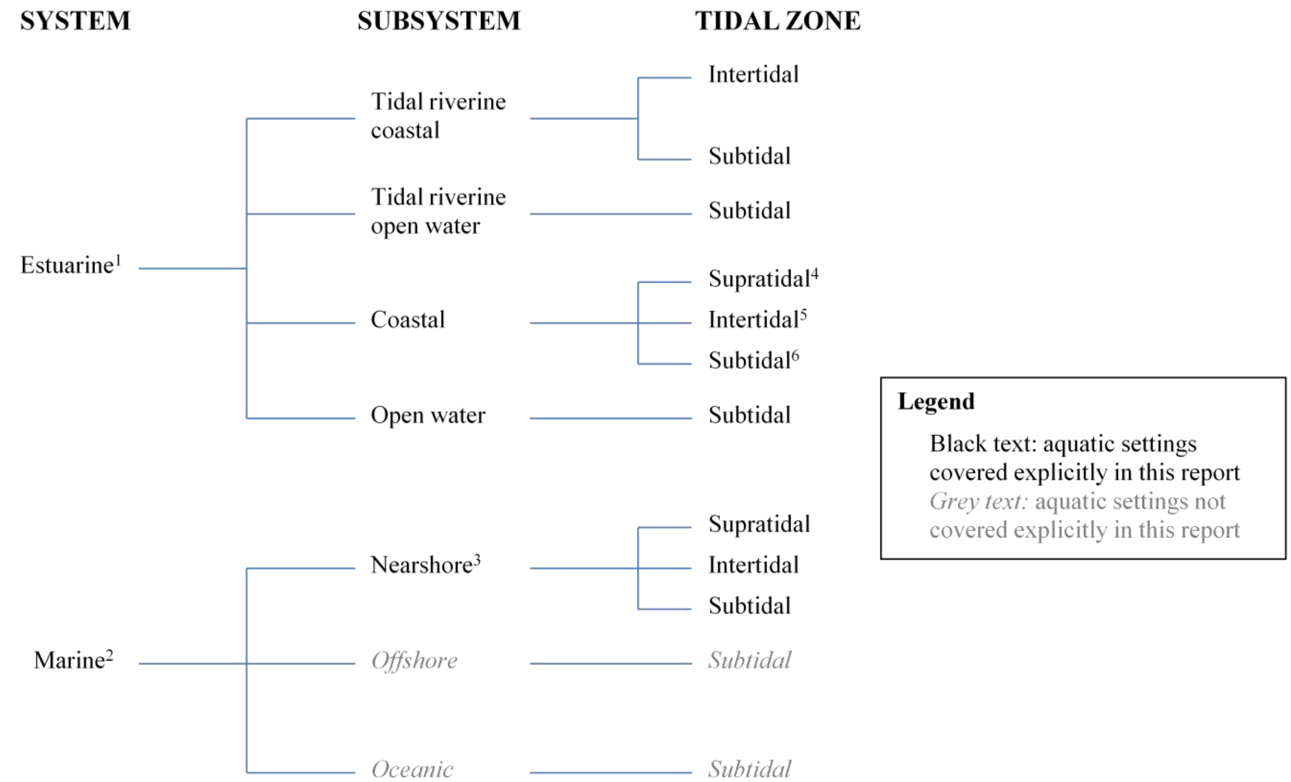
> *Given the stated familiarities with different coastal adaptation approaches, it appears as if most respondents may be considering techniques that are commonly used in coastal land use planning and hazard mitigation, and possibly not know about or appropriately consider approaches with which they are less familiar at this time. These knowledge gaps are clear targets for future outreach and training activities aimed at coastal managers (Finzi Hart et al., 2012, p. 17).*

The activity areas for coastal ecosystems and habitats are:

1. Track climate change effects and compare management options in the intertidal zone
2. Address potential changes in phenology and food webs due to acidified and low-oxygen ocean conditions
3. Characterize eelgrass and kelp habitats and identify priority areas
4. Inform cost estimates and vulnerability assessments related to altered coastal flooding regimes in Puget Sound and the California Current Region

Within an activity area, several specific activities requested by project participants are described. The description includes information on how many project participants identified the activity and the climate change-related challenges associated with pursuing the activity. To provide information to the NPLCC about when, where, and under what circumstances support is requested, participant evaluations of the activity across the four evaluation criteria are synthesized:

- *Decision-relevance* indicates which decisions the activity would help inform or guide.
- *Timeline or sense of urgency* indicates when the activity is needed and provides a sense of why and how important, or urgent, it is to pursue the activity.
- *Spatial and temporal scale* identifies the necessary geographic region or spatial coverage for the activity and whether the activity is needed on an annual, seasonal, daily, etc. timescale.
- *Partners and ongoing efforts* identifies the people, partnerships, and organizations that might already have information about the activity or might be well suited to develop it.



Notes

1. "The Estuarine System is defined by salinity and geomorphology…[and] includes tidally influenced waters that (a) have an open-surface connection to the sea, (b) are regularly diluted by freshwater runoff from land, and (c) exhibit some degree of land enclosure. The Estuarine System extends upstream to the head of tide and seaward to the mouth of the estuary" (MCSDC 2012, p. 26-27).
2. "The Marine System is defined by salinity,…has little or no significant dilution from fresh water except near the mouths of estuaries and rivers…[and] includes all non-estuarine waters from the coastline to the central oceans" (MCSDC 2012, p. 30).
3. "The Marine Nearshore Subsystem extends from the landward limit of the Marine System to the 30 meter depth contour…The photic zone extends through the entire water column except in extreme cases (Kleypas, McManus and Menez 1999). The presence of nutrients and light support the growth of vegetation on the bottom including seagrass and macroalgal beds..." (MCSDC 2012, p. 31).
4. The areas above MHHW affected by wave splash and overwash. Areas affected only by wind-driven spray are not included (MCSDC 2012, p. 31).
5. The areas between MLLW and MHHW. They are regularly and periodically exposed and flooded by tidal action (MCSDC 2012, p. 31).
6. The areas below MLLW. They are generally continuously submerged (MCSDC 2012, p. 31).

Figure 3. Aquatic Setting Hierarchy Showing Estuarine and Marine System, Subsystem, and Tidal Zone (adapted from MCSDC 2012, Fig. 4.1, p. 26)

1. Track climate change effects and compare management options in the marine nearshore and estuarine environment

The marine nearshore and estuarine environment (MCSDC 2012) was a topic of discussion in seven of thirteen web-based focus groups, all three in-person workshops, and in several survey responses. Most discussion focused on tidal wetland and estuarine habitats. Four activities were suggested:

- Characterize and track climate change effects on physical, chemical, and ecological processes in the marine nearshore and estuarine environment
- Map and characterize the marine nearshore and estuarine environment and associated habitats
- Assess vulnerability and compare management options
- Compare decision-support tools and share datasets

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	✓
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	✓
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

The specific suggestions in each of these activity areas are also reflected in NOAA‟s (2011) assessment of climate-related challenges and needs for coastal decision makers, specifically science-based assessments and predictions of sea-level change impacts to coastal ecosystems. This information would "inform decisions on the conservation and restoration of coastal wetlands, and [would] guide permitting and other land-use policies" (NOAA 2011, p. 14). These include:

- Issues and information related to nearshore water circulation, shoreline stability and erosion, coastal hazards, and ocean acidification
- Ways to design and prioritize restoration projects given sea-level and climate change predictions
- Better understanding of natural erosion and deposition cycles in tidal marshes and sediment trapping and accretion
- Landscape response to sea-level and salinity changes
- Natural resource mapping and identification of high-priority areas and sea-level rise impacts
- Models that predict migration or vertical accretion of coastal wetlands and beaches
- Data and tools to predict impacts on habitats (NOAA 2011, p. 14).

A number of data and modeling requests made by project participants were also identified in NOAA‟s needs assessment. These range from high-resolution imaging for the coastline to models integrating multiple effects or changes:

- High-resolution topography and bathymetry at consistent temporal and spatial coverage
- Inundation and tidal elevation maps
- Historic and current land cover classification maps
- Additional surface elevation tables and water-level stations
- Wave heights, precipitation and wind data
- Shoreline change modeling
- Combined models of inundation and shoreline erosion that also incorporate changes in coastal geomorphology, hydrological conditions, and human alterations and response
- Local- and regional-scale modeling and projections of specific ecosystems (NOAA 2011, p. 13).

Characterize and track climate change effects on physical, chemical, and ecological processes in the marine nearshore and estuarine environment

Project participants from all five marine ecosystem web-based focus groups, the Puget Sound and Georgia Basin Freshwater and Coastal Temperate Rainforest Ecosystem web-based focus groups, all three workshops, and several survey respondents suggested pursuing projects and activities that would advance efforts to better understand the dynamic physical, chemical, and ecological processes at work in the marine nearshore and estuarine environment. The interaction of the sediment regime, hydrologic regime, and sea-level rise will determine the capacity of tidal wetlands and estuaries to keep pace with sea-level rise (Survey Respondent 29, California Current Marine #1). Specific research areas are:

- Measure sediment accretion, subsidence, flux, and transport
- Measure and monitor tidal elevation and isostatic rebound
- Study and characterize sedimentation processes and vegetation composition in the upper estuary and riverine areas that determine sediment input to the lower estuary and beaches
- Acquire fundamental data and develop decision-support tools for coastal erosion
- Assess changes in estuary character and processes due to changing freshwater input, estuarine water quality, and salinity

Measure sediment accretion, subsidence, flux, and transport

Project participants from the Puget Sound and Georgia Basin Freshwater, California Current Marine #1, and California Current Marine #2 web-based focus groups, the Portland workshop, and the survey suggested characterizing the sediment regime by measuring sediment accretion, subsidence, flux, and transport in coastal ecosystems because *there is a data gap at our day-to-day operations level to see if we should pursue projects or if we should discard them because we think they will be inundated… (California Current Marine #1).*

Furthermore, an improved understanding of the sediment regime would assist resource managers and conservation practitioners in their efforts to enable wetlands to keep pace with sea-level rise:

> *[Need to identify and assess] methods to enhance sediment deposition and production of organic matter, to maximize the potential for wetlands to keep pace with sea level rise (California Current Marine #1).*

Participants noted that altered precipitation and snowmelt patterns in the NPLCC‟s watersheds will be reflected in altered sediment input to rivers and streams as well as changes to streamflow regimes. Along the coast, hydrologic changes will also affect the rate and magnitude of bluff failure and retreat. Both these processes, in turn, affect sediment supply to the coastal environment. Bluff failure and retreat, for example, *are known to be significant sources of sediment to beaches (Puget Sound and Georgia Basin Freshwater).*

Participants recognized these processes as important for understanding and responding to the impacts of climate change on coastal ecosystems, but in most cases, information is insufficient. Web-based focus group and in-person workshop participants noted that *in terms of trying to make projections or have an understanding of nearshore response [to sea-level rise and other climate change impacts], we need a better understanding of sediment sources and supplies to the nearshore (Puget Sound and Georgia Basin Freshwater)* including *―...how sediment supply from rivers and bluff retreat might change with future climate change" (Survey Respondent 52).* This includes past, current, and future sediment regimes, all of which inform understanding of current sediment processes and projections of future conditions (California Current Marine #1). Specific data and information requests include:

- Sediment input from the freshwater system, including amount, timing, and patterns
- Sediment supply, flux, and transport along the coast, including seasonal variation
- Rates of subsidence and accretion, including seasonal variation

To assess current and future sediment regimes, information on the amount, timing, and pattern of sediment input from the freshwater system is requested:

> *...to assess current and future sediment regimes information is needed on sediment loads carried by rivers and marine sediments carried into estuaries, and how these may affect estuarine wetlands – such as predicted loads, seasonal distribution of loads, and likely deposition patterns. Information will need to be spatially explicit and will need to specifically address predicted future seasonal variation in precipitation… (California Current Marine #1).*

In addition, estuarine and alongshore sediment transport data should be collected where sea-level rise is projected to be highest with regard to potential habitat change (Portland workshop). This will be relevant for decisions about restoration planning and permitting (Portland workshop).

To anticipate the response of unconsolidated ocean beaches to changes in sea level (and changes in storm frequency, timing, and intensity and associated extreme wave frequency, timing, and height), an understanding of sediment sources, sinks, and fluxes is essential (California Current Marine #1).

Sediment flux modeling is challenging and costly, but currently, most managers are left to rely on "bath tub" models which are inadequate for dynamic systems, and in some cases, may be misleading:

> *It is expensive, but for sandy ocean beaches better information on sediment flux is needed. They have to apply poor models so it leaves them handicapped in predicting those changes (California Current Marine #1).*

The interaction of sediment processes, in addition to tectonic activity and isostatic rebound, is ultimately reflected in rates of subsidence and accretion in the coastal intertidal zone. Therefore, in addition to an improved understanding of sediment supply, flux, and transport along the coast, project participants requested an assessment of rates of accretion, subsidence, and uplift in the intertidal zone (Survey Respondent 42, California Current Marine #1).[93] Information on subsidence in former coastal wetlands would be helpful for planning restoration projects such as reconnecting old wetlands that have been diked or leveed (California Current Marine #2). Results from the assessments would also be inputs to "*…various physical and biological models we would like to use for climate change scenarios and predictions." (Survey Respondent 42).*

The assessment should target key locations such as Humboldt Bay (California Current Marine #1), land subsidence behind dikes and levees (Portland workshop), and least-disturbed, unrestored, and restoring tidal wetlands. Potential partners include:

- U.S. EPA researchers in Newport, Oregon are currently studying accretion rates using marker horizon plots in several estuaries (California Current Marine #1).
- Pat Shafroth (U.S. Geological Survey) is a suggested contact for information on watershed geomorphology and vegetation ecology. Recent and current work includes baseline hydrologic studies in the Lower Elwha River (WA) prior to dam removal, a report on the vegetation of the Elwha River Estuary, general research on riparian vegetation and floodplain sediment responses to dam removal, and investigation of invasive species in riparian ecosystems, emphasizing the ecology, restoration implications, effects of climate change, and interactions with streamflow and fluvial responses.
- Christopher Magirl (U.S. Geological Survey, Water Science Center) is a suggested contact for geomorphology and sediment transport in Puget Sound and the Strait of Juan de Fuca. Studies include characterization of geomorphology (e.g., current and projected sediment regime), hydrology, channel-conveyance and capacity, and/or habitats of the Elwha River and associated coastal habitats, lower Puyallup, White and Carbon Rivers, and other major rivers draining into Puget Sound.
- Guy Gelfenbaum (U.S. Geological Survey) is a suggested contact for information on nearshore sediment transport and effects. Other interests include large-scale coastal evolution and a focus on Southwest Washington.

[93] Additional information on uplift is available in the next section.

- Sediment Elevation Tables (SETs) [94] are operating at South Slough National Estuarine Research Reserve and the Nisqually National Wildlife Refuge (California Current Marine #1, Puget Sound and Georgia Basin Marine).

Measure and monitor tidal elevation and isostatic rebound

Project participants noted that as sea levels rise and tidal elevation changes, the effect on coastal habitats and communities may be mitigated or exacerbated by the rate and direction of land movement due to vertical land motions, which include isostatic rebound, tectonic action, subsidence, accretion, and fluid withdrawal and recharge (see also, NRC 2012). Subsidence and accretion were covered in the previous section; tidal elevation and isostatic rebound are covered in this section.[95] Four web-based focus groups,[96] the Portland and Juneau workshops, and a few survey respondents identified baseline data on vertical land motions as critical inputs to models, mapping exercises, and for making informed conservation and resource management decisions:

> *…vertical elevation data will be important for every community (California Current Marine #2)* and *is a big issue in Clallam County (Puget Sound and Georgia Basin Marine).*
>
> *[We need to] understand how sea-level rise will affect habitat and infrastructure in the area and how that relates to other kinds of changes… what type of habitats will be changing into over time? What types are likely to be more common or less common over time? (Southcentral and Southeast Alaska Marine).*
>
> *[We need] accurate vertical elevation data along the coast for restoration projects and for use in sea level rise models (California Current Marine #2).*

Tidal gauges provide baseline information used in a variety of applications and decisions including the determination of mean high tide, planning and permitting processes, and identifying the boundaries of political jurisdictions. Strategically located tidal gauges would also refine estimates of mean sea level, assist with identifying floods and flood-related impacts to tidal wetlands, and would facilitate strategic restoration. Portland workshop participants identified the urgency as "high" for restoration, and suggested the Permanent Service for Mean Sea Level (PSMSL) in the United Kingdom as a potential partner. To be strategic, tidal gauges should be placed in locations where they would be most relevant such as the outer coast, bays, and upstream estuarine areas (California Current Marine #1, Portland workshop).

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[94] Cahoon and Lynch (2010) describe SETs as "portable mechanical leveling device[s] for measuring the relative elevation change of wetland sediments."

[95] Project participants did not make specific suggestions to address vertical land motions due to tectonic activity and fluid withdrawal and recharge. In the southern NPLCC region, tectonic activity in the Cascadia Subduction Zone, where the Juan de Fuca plate is subsiding under the North American plate, is causing uplift along the coasts of northern California, Oregon, Washington, and southern British Columbia (NRC 2012). The uplift mitigates increases in absolute sea level and in some places, is outpacing sea-level rise currently. The withdrawal and recharge of fluids such as groundwater and oil also causes vertical land motion, though at spatial scales too small to affect relative sea level in the southern NPLCC region (NRC 2012).

[96] The four web-based focus groups represented are Southcentral and Southeast Alaska Marine, Puget Sound and Georgia Basin Marine, and California Current #1 and #2.

Web-based focus group participants also identified tidal gauge data as a potential priority:

> *If you are finding that a certain factor is a controlling factor, that becomes a priority – like tidal water level data which is…a controlling factor for ecosystem and structural need (California Current Marine #1).*

> *We need an improved tide station network: updates to existing data; long-term stations in more estuaries; more up-estuary secondary and tertiary gauges. We [also] need updated values for —highest measured tide". This value, used in regulatory contexts, is outdated or nonexistent for many estuaries. We need information on how the[se] hydrologic elements will interact with the sediment and organic matter accretion elements (California Current Marine #1).*

To further inform decisions about where to place tidal gauges, project participants requested baseline data on sea-level rise. This information would also inform restoration planning and permitting. Participants observed that many historic sea level records in the NPLCC region are widely dispersed in towns and cities and undigitized (the earliest records may be handwritten), which means they are generally unavailable for use as a baseline value in research studies or for decision-making due to the time and money needed to acquire them. Workshop participants identified mining old data for historic sea levels as a key activity in the NPLCC region, citing its relevance for restoration planning and permitting and its usefulness for addressing uncertainties over political boundaries. Similarly, one webinar and workshop participant noted that old aerial photos can provide information about historic shoreline position and movements, as well as estuarine inundation and channel configuration. Following the example of the Permanent Service for Mean Sea Level (PSMSL) in the United Kingdom, one participant suggested digitizing historic sea level records as a resource for those working in the region. The PSMSL has advertised matching funding for mining tidal data.

Finally, project participants requested additional information on current and future rates of isostatic rebound throughout Alaska and in particular locations such as the Gastineau Channel near Juneau (Juneau workshop). For example, information on if and when "total rebound" may occur would be *good information for students on how the glacier affects the community and climate* (Juneau workshop). Project participants also requested information on how the interaction of isostatic rebound, sea level, and patterns of nutrient and freshwater input are likely to affect intertidal and nearshore habitats and productivity (Southcentral and Southeast Alaska Marine, Juneau workshop). Isostatic rebound occurs when land uplifts or "rebounds" after a glacier retreats and its weight is removed from the land below. In southcentral and southeast Alaska, isostatic rebound is currently outpacing the rate of sea-level rise in some locations (NOAA 2012b).

Study and characterize sedimentation processes and vegetation composition in the upper estuary and riverine areas that determine sediment input to the lower estuary and beaches

A number of research topics related to processes in the upper estuary and riverine areas that determine sediment input to the lower estuary and beaches were identified:

> *…we need spatially explicit information on likely future changes to streambed/riverbed configuration and how those patterns may affect tidal forcing, particularly in middle and upper estuaries. How might dredging affect these patterns/scenarios?... [What is the] role of channel excavation in restoration trajectory, as it relates to soil type, wetland surface elevation, landscape setting and geomorphology, freshwater flow etc.? (California Current Marine #1).*

> *We need information for our region on contributions of belowground organic matter production to equilibration of wetland surface elevation with sea level… (California Current Marine #1).*

> *In wetland classes dominated by woody vegetation such as tidal swamps, information is needed on the importance of woody vegetation to restoration trajectory, sediment detention, organic matter production, and channel forming processes in tidal wetlands… (California Current Marine #1).*

Research was also requested on the role of beavers over time in *maintaining tidal wetland surface elevations relative to rising sea levels (California Current Marine #1)*. These processes are important because, for example, areas with large stretches of shoreline such as many of Washington and Oregon‟s sandy beaches would lose habitat if sediment supply to the intertidal zone decreased (Puget Sound and Georgia Basin Marine).

Acquire fundamental data and develop decision-support tools for coastal erosion

Survey respondents suggested filling several fundamental data gaps and developing decision-support tools to address coastal erosion. Survey Respondent 33 drew from a recent white paper on climate change research needs from the California Coastal Commission. Fundamental data needs identified by the California Coastal Commission range from a better characterization of the nearshore wave environment to a coast-wide survey of topography and a better understanding of how changing patterns of wave energy systems may affect sediment transport:

> *―Determine how best to characterize the near-shore wave environment and developing statewide, historical wave climatology on this basis that is easily available on the Internet…" (Survey Respondent 33, also* see p. 3 of California Coastal Commission, 2008*).*

> *―..Continue, expand, and coordinate the existing LIDAR survey programs to systematically survey the entire California coast with sufficient regularity to establish baseline conditions, and identify episodic and chronic changes from and variations in the*

current baseline…" (Survey Respondent 33, also see p. 3 of California Coastal Commission, 2008*).*

―.Study of wave energy and the potential to alter coastal processes due to the resulting drop in nearshore wave energy…" (Survey Respondent 33, also see p. 6 of California Coastal Commission, 2008*).*

―Studyof…alteration in sediment transport patterns if wave energy systems reduce ‗summer' season wave energy critical for beach build-up while having minimal impact on ‗winter' season wave energy that carries sediment offshore…" (Survey Respondent 33; also see p. 6 of California Coastal Commission, 2008*).*

Addressing fundamental data gaps would respond to key challenges identified by project participants, for example:

On the Straight [of Juan de Fuca] the LiDAR data is really insufficient. The bluffs make it really difficult. The shadowing effect of the bluffs make it difficult…Without this we can't make predictions on sediment and…how they are going to change with events like the Elwha Dam Removal or additional armoring, much less with climate change impacts (Puget Sound and Georgia Basin Marine).

Addressing fundamental data gaps would also assist efforts to develop beach loss and cliff erosion predictions and a model relating the increase in long-term bluff retreat to sea-level rise, both of which were also identified as needs by the California Coastal Commission and could be used to inform policy decisions for future coastal development (Survey Respondent 33, also see p. 3 of California Coastal Commission, 2008).

Decision-support tools include identifying and mapping vulnerable areas. These tools assist resource managers, conservation practitioners, and others in their efforts to examine options for adapting to sea-level changes and coastal erosion (Survey Respondent 33, see p. 3 of California Coastal Commission, 2008). For example, *―it is helpful to have practical information, including images (before and after) of options to decrease shore erosion…" (Survey Respondent 4).* Project participants working in British Columbia produced "ground-truthed" maps of shorelines sensitive to erosion and provided them to the Ministry of Environment (Survey Respondent 24). They also use the maps and associated ratings in their own work (Survey Respondent 24). The California Coastal Commission suggests a decision-support tool based on wave and storm conditions to determine the location of habitats vulnerable to coastal erosion:

―…Develop and implement systematic, state-wide coastal storm monitoring protocols to identify and record significant wave and storm conditions, maximum overtopping, run-up heights, beach erosion, and wave-induced bluff erosion to determine which coastal locations are most vulnerable to future sea level rise…" (Survey Respondent 33; also see p. 2-3 of California Coastal Commission, 2008*).*

To communicate information on coastal processes to the public, web-based resources such as Green Shores were suggested:

> ―..*Green Shores is a trademarked body of knowledge which helps us present information on coastal processes to the public…" (Survey Respondent 24)*

As stated on their website, "the Green Shores project promotes sustainable use of coastal ecosystems through planning and design that recognizes the ecological features and functions of coastal systems" and "provides options and tools for a wide range of planning, design and construction professionals who are interested in minimizing the environmental impacts of their projects in a cost effective manner."

Assess changes in estuary character and processes due to changing freshwater input, estuarine water quality, and salinity

Research on changes in estuary character and processes should focus on changes in freshwater input over the next ten to 100 years in the intertidal zone and the nearshore/terrestrial interface (Portland workshop). The research was requested because, as one web-based focus group participant stated:

> *I have very little understanding of how these estuaries are going to change in terms of freshwater input and the types of currents changing and how that will change the character of estuaries and the relationship between the marine water side of that and the intertidal areas and the areas directly adjacent to that… [I am] trying to understand the changes we can anticipate over time with fresh water input (Southcentral and Southeast Alaska Marine).*

In partnership with state and federal agencies, additional research on estuarine water quality and salinity is suggested for estuaries and the broader salt/freshwater interface. This information would be relevant for determining future habitat and species distributions. Examples of additional research include:

> *a way to predict salinity regimes (tidal, seasonal) with changing sea level and precipitation patterns, quantitative information on salinity tolerances of dominant tidal wetland plant species, and information on the interactions of predicted hydrologic and sediment patterns and resulting effects on salinity regimes (California Current Marine #1).*

Research on plant tolerance to salinity and efforts to predict salinity regimes could be informed by enhanced monitoring. For example, installing extended deployment sondes that include salinity and conductivity probes could be used to monitor changes in marine penetration and shifts in oligohaline and tidal-fresh regions in the upper parts of estuaries (Portland workshop). Sondes are water quality instruments that measure a number of variables in the water column[97] (Portland workshop).

[97] NOAA Ocean Explorer (2006)

Map and characterize the marine nearshore and estuarine environment and associated habitats

Project participants from the California Current Marine #1 and #2 web-based focus groups, all three workshops, and survey respondents repeatedly requested assistance to characterize and map the intertidal zone and associated habitats. Specific characterization and mapping requests fall into the following three categories, each of which is discussed in turn:

- Use LiDAR to survey the intertidal zone and produce high-resolution surface models
- Identify the current and potential future distribution of intertidal habitats and species
- Enhanced and expanded mapping of the intertidal zone, with an emphasis on tidal wetlands and estuaries

Use LiDAR to survey the intertidal zone and produce high-resolution surface models

Spatial data describing the topographic surface in the intertidal zone is a key source of baseline information for a range of research, modeling, and management efforts, including the projections of future habitat distribution discussed later in this section. A lack of spatial data for the intertidal zone was also identified as a significant challenge:

> *―At the moment, the most pressing challenge is the lack of high-quality spatial data describing the topographic surface at the intertidal zone. Water (tides), sparse tidal data (both temporal and spatial), and lagging implementation of recent technology have hindered our efforts to collect or derive good surface models of the intertidal zone" (Survey Respondent 27).*

Two suggestions to address this challenge were made by project participants in the Portland workshop. The first suggestion is to conduct high-resolution Light Detection and Range (LiDAR) analysis at key locations in the NPLCC region during the lowest tide. When collected during very low tide in areas with minimal vegetation, LiDAR data can be used to develop accurate high resolution surface models of the intertidal zone. Where dense vegetation is present, other methods such as real-time kinematic Global Positioning Systems (RTK GPS) can provide accurate elevation information. Pacific Coast LiDAR is available from:

- Digital Coast, which is a NOAA Coastal Services Center decision-support system. Among other resources, it stores coastal LiDAR data for all U.S. coastal states, standardized in a single format, projection, and datum.
- USGS‟s Center for LiDAR Information Coordination and Knowledge (CLICK), which facilitates "data access, user coordination and education of LiDAR remote sensing for scientific needs." For example, publicly available LiDAR data is available on the site through the LiDAR viewer.

Other LiDAR resources include:

- The Lidar for Science and Resource Management (LSRM) project, which is sponsored by the USGS Coastal and Marine Geology Program. LSRM is "supporting the creation of new capabilities for the synoptic remote sensing of coastal-marine and terrestrial environments based on aircraft and satellite sensors." LSRM is working with the USGS Pacific Coastal and Marine Science Center to expand these resources to the Pacific Coast. These resources include Experimental Advanced Airborne Research Lidar (EARRL), "an airborne lidar system that provides unique capabilities to survey coral reefs, nearshore benthic habitats, coastal vegetation, and sandy beaches," and many other resources.

- For assistance with underwater aquatic vegetation, the U.S. Geological Survey on the East Coast was suggested. Specifically, John Brock with the USGS Coastal and Marine Geology Program at the National Center in Reston, VA and Hilary Neckles with USGS Patuxent Wildlife Research Center in Augusta, ME were suggested.
- For assistance with terrestrial acquisitions, an academic partner such as a civil engineer was suggested. For example, Mike Olsen with Oregon State University"s School of Civil Engineering has conducted LiDAR analyses of Pacific coastal areas from southern California to Washington, as well as internationally. In the Puget Sound area, the U.S. Geological Survey has also conducted similar work. Dean Gesch or Vivian Queija of USGS Earth Resources Observation and Science (EROS) Center are suggested contacts (search Publications by Current Staff for more information).

The second suggestion is to propose the NPLCC region as a project for the National Coastal Mapping Program (NCMP). NCMP is an above and below water LiDAR map administered by the U.S. Army Corps of Engineers (USACE).[98] The maps produced through the collaboration would inform key research and modeling projects and activities identified by project participants including efforts to:

- Determine the size of the intertidal zone, both now and in the future. This affects federal, state, and private land ownership; for example, U.S. FWS refuge lands.
- Support modeling of the rocky intertidal ecosystem.
- Support modeling of beach habitat sediment transport.
- Detect habitat changes through interval acquisitions.

NCMP is a collaboration between USACE, the National Oceanic and Atmospheric Administration, the U.S. Naval Oceanographic Office, the U.S. Geological Survey, and perhaps others. The program began in the early 2000s and acquired current topobathy maps of the East Coast, Great Lakes, and southern coasts. Data was also acquired for the Pacific Coast. Current topobathy data for the southern California coast has been released, and similar data for northern California, Oregon, and Washington will be released in one to two years (late 2012 to late 2013). A number of publications describing the project and data have also been released.[99]

Identify the current and potential future distribution of intertidal habitats and species

Information on the availability and distribution of intertidal habitats and species over time across the NPLCC region would inform management of the intertidal zone, including invasive species management, identification of areas for conservation, acquisition, and enhancement, and efficient investment of limited

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[98] Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) (2012)
[99] Guenther et al. (2002), Irish (2000), Irish and Lillycrop (1999)

conservation and restoration dollars (Portland workshop, Juneau workshop). Key data inputs include information on salinity, circulation, temperature, and potential changes to phenology (Portland workshop). A focus on information at local scales is suggested (Portland workshop). This is a long-term project with potential partners available in states, provinces, the U.S. Forest Service, the U.S. National Park Service, and wildlife and natural resource agencies and programs within these entities (Portland workshop, Juneau workshop). The Washington State Department of Ecology‟s coastal atlas may also be of assistance:

> *…maybe the DOE coastal atlas to project that type of info [on potential future coastal wetland habitat distribution]. Seems like it is a tool that is used often to see aerial views (Puget Sound and Georgia Basin Marine).*

Within this broad research topic, project participants provided three specific suggestions for future work:

- A NPLCC-wide assessment to determine intertidal habitat persistence in light of sea-level rise and other stressors.
- Further characterization of rocky intertidal habitats.
- Mapping and quantifying current and potential tidal wetland and marsh migration.

A NPLCC-wide assessment to determine intertidal habitat persistence would combine projected rates of sea-level rise, vertical land motions (see previous sub-section of this chapter, p. 93-94), and changes in freshwater and nutrient inputs to determine their combined effect on physical processes and ecological risk, which in turn would help identify which habitats are likely to persist over time (Portland workshop, Juneau workshop). The assessment would therefore inform assessments of vulnerability, risk, and restoration potential (Portland workshop). While the emphasis is on changes occurring in the next ten to thirty years, a 50 to 100-year timescale is also suggested (Portland workshop). In Oregon‟s intertidal zone, tidal swamps have been identified as key tidal wetlands to characterize:

> *We need better characterization of little-understood and highly impacted tidal swamp ecosystems, to avoid future losses. Tidal swamps are primarily located in the middle to upper estuary zone that will constitute the landward migration zone for bay fringe tidal wetlands. Tidal swamps once constituted a high proportion of tidal wetlands in Oregon, but are now almost completely gone from the landscape (California Current Marine #1).*

Further characterization of rocky intertidal habitats is also requested to model relationships and responses to climate change. Key data inputs include coastal topobathymetry such as Coastal Zone Mapping and Imaging LiDAR (CZMIL) and ecological data on species occurrence, distribution, and dynamics (e.g., algae and invertebrates):

> *―Continuing implementation of coastal topobathymetry projects (e.g., CZMIL) will assist with our quantification of rocky intertidal habitat. Ecological data (e.g., species occurrence, distribution, and dynamics) for rocky intertidal organisms are required to model relationships and responses to climate change. These include sampling algae and invertebrates within the rocky intertidal zone, as well as key vertebrates that utilize and influence the rocky intertidal zone" (Survey Respondent 7).*

Mapping and quantifying current and potential wetland and marsh migration would help identify vulnerability and resiliency to climate change, as well as areas for conservation, acquisition, restoration, and enhancement (Arcata workshop). For example, quantifying the potential for marsh migration would inform decisions about prioritization of wetland restoration and how to manage or not manage invasive species (Arcata workshop). Maps of current and potential future distribution would help identify critical habitat buffers for coastal zones and wetlands that may serve as carbon sinks (Arcata workshop). Baseline information such as the current location, distribution, and composition and extent of communities is requested as soon as possible because it is currently changing (Arcata workshop). This information is also high-priority information to track over time (Arcata workshop).

A watershed-based scale that includes inland and upland springs and wetlands, and extends into and through the intertidal zone is suggested (Arcata workshop). To inform a baseline assessment, the temporal scale should begin with changes in the Holocene (paleoecology) and include specific information on the past 100 years to present-day (Arcata workshop). However, the paleoecological and recent historical information is less urgent to acquire compared to characterizing current conditions (Arcata workshop). Potential partners include Tribes, the U.S. Geological Survey, U.S. Fish and Wildlife Service, NOAA, U.S. EPA, Army Corps of Engineers, and the USDA. A range of state, local, academic, and non-governmental institutions are also potential partners: California Department of Fish & Game, California Water Resources and coastal communities, county and local government, the Pacific Institute, academia, resource users, NGOs, and environmental groups. Within government, the permitting agencies are potential partners. The National Wetlands Association was also cited as a potential partner, but a search for the organization on Google returned no results. The National Wetlands Inventory or Association of State Wetland Managers may have been the intended partner. Finally, ShoreZone mapping of both geomorphic and biological resources is available for the coasts of Alaska, British Columbia, and Washington. More information on ShoreZone can be found in the next section.

Enhanced and expanded mapping of the intertidal zone, with an emphasis on tidal wetlands and estuaries

Participants from the California Current Marine #1 web-based focus group and Portland workshop identified classification and mapping of the supra-, intra-, and sub-tidal scales to inform research and management priority setting for conservation and adaptation as a short-term science focus. For example:

> *We still need mapping and detailed characterization of all current and historic (impacted) tidal wetlands for a number of our estuaries… (California Current Marine #1).*

Downscaled data on temperature and other physical processes in these habitats was also requested in the short-term to inform research, management, and climate change adaptation for species inhabiting tidal environments. Laura Brophy and her team at Green Point Consulting are potential partners. They have mapped and characterized all current and historical tidal wetlands in the Nehalem, Yaquina, Alsea, Siuslaw, Umpqua, and Necanicum estuaries in Oregon, and plan to complete a similar assessment for Oregon‟s Tillamook Estuary in 2012.[100]

[100] Brophy (1999), Brophy (2005), Brophy (2010), Brophy and So (2005a, 2005b, 2005c)

In addition to maps of current and future habitat distribution, enhanced and expanded mapping of the vulnerability of estuaries, wetlands, aquatic connectivity, and other systems was also frequently requested by project participants. For example:

> *I would say as someone who is a liaison between people, they want maps. Where were tidal wetlands historically, now and in the future?...Right now we are using maps of migration zones for estuaries to help clients like land trusts to make decisions on where to protect lands so that there are areas for tidal wetlands to migrate to – those are useful (California Current Marine #1).*

To be relevant for decisions, participants provided two scales for wetland maps: at the level used for land use permitting and at the population segment level for use in Endangered Species Act restoration and recovery. Workshop participants emphasized that maps of wetlands should extend beyond the tidal interface to include freshwater and alpine wetlands. Key partners include ongoing restoration projects and the U.S. EPA, particularly opportunities to build on and intensify the National Wetland Condition Assessment.

These maps should be available throughout the NPLCC region and should include the location of current development pressures and groundwater sources. Southcentral and southeast Alaska was suggested as a potential priority region; participants in California are also seeking funding for wetland visualization tools and assistance mapping the intertidal zone:

> *I submitted a grant to Sea Grant to create a wetland visualization tool but it was not funded. I think that visualization tools are the way that most of us understand things the best. Under what scenarios, where will the water be and how can we prioritize? Where can wetlands migrate?....Cal Adapt might help. I do not know what tools are available. (California Current Marine #2).*

> *The one that I am struggling with is a decent base map of the interface between land and water (intertidal zone)...Using LIDAR to look at above and below water to provide a digital elevation map (DEM) of the interface where we have not had info in the past (California Current Marine #1).*

Ongoing efforts and potential partners to assist with enhancing and expanding mapping include ShoreZone, NetMap, and the Ecosystem-Based Management Tools Network. ShoreZone was identified as an ongoing effort in the Juneau workshop. NOAA describes ShoreZone as a "standardized system [that] catalogs both geomorphic and biological resources at mapping scales better than 1:10,000." The system uses "low-tide-oblique aerial imagery" and the user "can „fly the coastline (video), view still photos, and access biophysical data using our interactive ArcIMS web-site." Key characteristics of ShoreZone are described by Coastal and Ocean Resources, Inc. and include:

- Coastal imagery and mapped resources (e.g., shoreline sediments, eelgrass occurrence, wetland distribution) for southcentral and southeast Alaska, British Columbia, Washington, and Oregon. *Note: Additional information for British Columbia is also available via NOAA's Alaska ShoreZone website.*

- "Physical and biological characteristics of discrete coastal habitat units are mapped both along-shore and across-shore (including wave exposure, substrate type, sediment texture, intertidal organisms, subtidal algae, and some subtidal fauna)."
- Useful for science, education, and management as well as for "habitat suitability modeling in which mapped shorelines are examined to predict the distribution of habitats that would support a particular group or species of interest." Species of interest include invasive species in British Columbia, Alaska, and Washington, as well as Dungeness crab and spawning forage fish.

Workshop participants suggested expanding NetMap, which is a "community based watershed science system comprised of uniform digital watershed (map) databases, analysis tools, and technical support materials,"[101] to the entire NPLCC region. Many watersheds in the Pacific Northwest are already covered by NetMap. Specific examples of decision-relevance provided by the workshop participants are: informing regulatory decisions at the state-level and informing U.S. FWS Comprehensive Conservation Plans, which are completed every ten years.

Finally, project participants suggested acquiring additional geospatial data layers for streams, species distributions, and habitat composition in the next one to three years. Participants cited key benefits as making decisions clearer and for use in NetMap, which "is designed to integrate with ESRI ArcMap 9.2/9.3 and with non-propietary GIS systems."[102] A potential partner is the Ecosystem-Based Management Tools Network. Web-based focus group participants suggested a number of principles to guide the development and use of decision-support tools and systems; these are described in Chapter III.1.

Assess vulnerability and compare management options

Project participants from the California Current Marine #2 web-based focus group, Portland and Arcata workshops, and one survey respondent suggested vulnerability assessments and assistance comparing management and adaptation options for the intertidal zone. This information would help identify areas of resilience and vulnerability, which would inform decisions about where and when to conserve, restore, acquire, or enhance areas in the intertidal zone (Arcata workshop). Assessments of wetland vulnerability, for example, could be followed by identifying methods to support vertical accretion to keep pace with sea-level rise:

> *―Identify wetlands that are at risk of flooding and permanent inundation due to sea level rise or inadequate sediment supply. Identify ways to add sediment to wetlands for vertical accretion with sea level rise…" (Survey Respondent 33, also see p. 4 of California Coastal Commission, 2008).*

Given the role of wetlands as carbon sinks, development of predictive tools that could be use to determine the carbon sequestration benefit of wetland restoration options was also suggested:

> *―…Develop predictive tools to quantify potential CO_2 sequestration in tons per acre per year for different wetland, vegetation, or, soil types, and geographic regions (northern, central or southern California) to determine sequestration benefits from various wetland*

[101] NetMap: Community Watershed Data & Analysis System (2009)
[102] NetMap: Community Watershed Data & Analysis System (2009)

restoration options…" (Survey Respondent 33, also [see p. 5 of California Coastal Commission, 2008](#)*).*

As beaches narrow due to increased coastal squeeze, methods for "ecologically sound beach nourishment" would fill an existing knowledge gap:

> *… something that is facing the Coastal Commission more and more is beach nourishment projects where the coastal squeeze is causing beaches to become very narrow – many agencies just want to throw sand on beaches from different areas. Knowledge on ecologically sound beach nourishment is lacking (California Current Marine #2).*

More broadly, maps showing vulnerability to coastal squeeze across all habitat types have been suggested:

> —*.Easily updatable maps showing sea level rise under various climate change scenarios and locations of coastal squeeze – where sea level rise and existing development will squeeze out habitats such as beaches, coastal bluffs, dunes, and wetlands; Identify the most vulnerable coastal habitats and species across the coastal zone…" (Survey Respondent 33, also* [see p. 4 of California Coastal Commission, 2008](#)*).*

The wetland vulnerability assessment, tool and map development, and comparisons of response options could all inform decisions about where and when to initiate pilot projects and more comprehensive resource vulnerability assessments of cumulative impacts. This idea was suggested by Portland workshop participants. These pilot projects would construct and make use of conceptual models that integrate the various anticipated impacts of climate change on a discrete system or area of concern. The exercise could help managers identify tangible measures they could pursue now, could be used to focus monitoring strategies, would help identify information gaps and priorities, could help approximate areas and degrees of uncertainty, and would increase managers‟ confidence in their decision making.

Small, place-based pilot projects are suggested as a starting point, followed by analyses at multiple scales if the approach is productive and deemed to be useful. Partners include local governments, historical archives, and those with local knowledge. Two ongoing efforts were identified for their potential to provide guidance in assessing vulnerability and comparing management options:

- The Ni-les‟tun Tidal Marsh Restoration Project on Bandon Marsh National Wildlife Refuge was identified as an example for place-based pilot projects (see March 6, 2012 press release and Ni-les‟tun Tidal Marsh Restoration page). The 418-acre tidal marsh restoration project was completed in Summer 2011 and included partnership among the Coquille Indian Tribe, the Confederated Tribes of Siletz Indians, the Federal Highway Administration, U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Ducks Unlimited, and the Estuarine Technical Group of the Institute for Applied Ecology. Ni-les‟tun is one of two units in the Bandon Marsh National Wildlife Refuge, which is in turn a part of the larger Oregon Coast National Wildlife Refuge Complex.
- The governments of Canada and British Columbia produced a draft Marine Protected Area Network Strategy (PDF, 819 KB). The Strategy‟s ecological network design principles include

protection of unique or vulnerable habitats and "choos[ing] sites that are more likely to be resistant…or resilient…to climate change" (p. 12-13).

Compare decision-support tools and share datasets

Project participants from the Puget Sound and Georgia Basin Marine and California Current Marine #1 web-based focus groups and the Portland workshop requested sharing datasets and comparing the advantages and disadvantages of decision-support tools applicable to the marine nearshore and estuarine environment. NOAA"s needs assessment for coastal sea-level change identified a catalog of best management practices for climate adaptation strategies as a helpful resource for coastal decision makers (NOAA, 2011, p. 14). For general information on comparing decision-support tools, please see Chapter III.2 (p. 28). Comparing tools would address the challenges participants face with identifying which maps, models, and other decision-support tools are most applicable and dependable for their site and their particular research needs:

> *… The issue of scale is critical… Simple inundation models for unconsolidated systems like beaches can be misleading so we have to be cautious about that (California Current Marine #1).*
>
> *The Fish and Wildlife Service has been using the SLAMM model for refuge evaluation (and Ducks Unlimited has used it as well) for Puget Sound. SLAMM is generally good but not really good. I don't know how it should or could be changed… (Puget Sound and Georgia Basin Marine).*
>
> *… It seems like for a lot of these tools it is not useful if you are working on a specific site…We usually don't find that the maps are useful at the scale that they are usually at (California Current Marine #1).*

Workshop participants also requested a datasharing tool particular to estuarine wetlands:

> *We need a central source for information on existing data related to climate change impacts on estuarine wetlands (not necessarily the data, but links to data providers). The recent Coastal and Marine Spatial Planning workshop in Corvallis discussed this topic at length, and some staff at Oregon State Department of Land Conservation and Development are coordinating efforts in Oregon (California Current Marine #1).*

Participants stated that such a tool would be important for identifying where to direct current resources given available data and that it should be addressed in the next five years.

2. Address potential changes in phenology and food webs due to acidified and low-oxygen ocean conditions

Project participants in all three workshops, three of five marine ecosystem web-based focus groups, and the survey identified the biological and ecological effects of ocean acidification, hypoxia, and harmful algal blooms on phenology and the food web as a key uncertainty and topic for additional research in the NPLCC region. In fact, this was one of only three ecosystem-, habitat-, or species-based topics discussed in detail at all three workshops (the others were the marine nearshore and estuarine environment, see Section 1, p. 89 in this chapter, and Pacific salmon, see Chapter VIII.1, p. 150). Participants noted a better understanding of the interaction between hypoxia, harmful algal blooms, and acidified ocean waters would assist efforts to respond to potential changes to phenology and food web impacts. They consistently described ocean acidification and accompanying effects on phenology and food webs as one of the most important, urgent, and uncertain climate change issues to address:

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

> *…what are the feedback relationships with ocean acidification? (California Current Marine #1)*
>
> *In Oregon the big question is the impacts of climate change on the food web. This will impact what we will do as humans but also for wildlife. One example is: How will things like seabirds be impacted by ocean acidification? (California Current Marine #1)*
>
> *…powerful research by Oregon State University on dead zones and coastal events…we understand so little about the processes that are happening. There is a trade off. Upwelling creates nutrient enrichment…how much is bad and how much is good [and] what is the impact on the ecosystems? (California Current Marine #2).*

In the NPLCC region, current research has documented declines in ocean pH and early evidence from ecological studies indicates potential deleterious effects on economic and cultural resources throughout the NPLCC region. Requested activities in the NPLCC region therefore emphasize an improved understanding of biological and ecological effects, coordination of existing research efforts, modeling, and science communication and outreach to better understand potential future effects and inform management decisions. The three activities identified are:

- Increase research and research coordination on changes to phenology and food webs
- Model ocean conditions, particularly at regional and local scales
- Engage in science communication and outreach with resource managers and the public

These activities have also been identified in the Draft Strategic Plan for Federal Ocean Acidification Research and Monitoring (FOARAM). For example, the Plan‟s recommendations and goals emphasize:

- "Building upon existing systems and developing new technology and systems that strategically monitor chemical and biological impacts of ocean acidification…
- Ensuring that ocean acidification data are properly managed and integrated across disciplinary, organizational, and data management technology boundaries…
- Examin[ing] species-specific physiological responses to ocean acidification and its interactions with other stressors [and] impacts to marine food webs and ecosystems…
- Developing comprehensive models to predict changes in the ocean carbon cycle and impacts on marine ecosystems and organisms…
- Designing and coordinating activities that foster ocean acidification literacy through educational resources and public outreach…
- Ensuring that results and assessments of monitoring and research efforts are accessible to and understandable by managers, policy makers, and the general public" (Interagency Working Group on Ocean Acidification, 2012, PDF available here, 1.71 MB).

Further, the activity areas are consistent with the National Research Council Report on Ocean Acidification, which frames its recommendations around six key elements including a robust observing network, research to fulfill critical information needs, and assessments and support to provide relevant information to decision makers (Levison 2012, p. 12). The focus on the regional scale is reflected in NOAA‟s research plan for ocean acidification, which will be "executed at the regional level with strong national coordination" (NOAA 2010, p. ix). Finally, the Washington State Blue Ribbon Panel on Ocean Acidification (2012) released a report detailing the impacts of ocean acidification on Washington‟s ecosystems, economy, and culture. The Panel‟s forty-two recommended actions fall into six Major Action Areas, several of which are consistent with the activity areas identified by project participants:

1. Reduce emissions of carbon dioxide.
2. Reduce local land-based contributions to ocean acidification.
3. Increase our ability to adapt to and remediate the impacts of ocean acidification.
4. Invest in Washington‟s ability to monitor and investigate the causes and effects of ocean acidification.
5. Inform, educate, and engage stakeholders, the public, and decision makers in responding to ocean acidification.
6. Maintain a sustainable and coordinated focus on ocean acidification at all levels of government.

Increase research and research coordination on changes to phenology and food webs

To better understand potential changes to phenological relationships and the food web as a result of acidified and low-oxygen ocean conditions, project participants suggested coordinated research on the following topics:

- The relationship between carbon dioxide (CO_2), temperature, dissolved oxygen, current speed and direction, and other factors in the oceans, including the effects on primary productivity, food webs, and specific projections on likely low pH upwelling zones
- Threshold CO_2 concentrations that initiate extinctions of marine organisms
- Nutrient loading, particularly in urban watersheds such as the Puget Sound: Nutrient loading may induce or exacerbate low pH conditions.
- Specific studies of potential effects on economically and culturally significant species such as shellfish, for example evaluation of harmful algal blooms

Participants stated that in addition to harmful algal blooms, contaminants, and monitoring of habitat types,[103] physical and chemical monitoring of ocean acidification, currents, temperature, and other factors are long-term, foundational inputs to Coastal and Marine Spatial Planning (CMSP), Ecosystem-Based Management (EBM), and ocean policies such as the U.S. National Ocean Policy. Changes to the food web would impact decisions for marine fisheries and could affect the food supply. Information on harmful algal blooms would help protect public health, cultural food sources, and recreational harvest (e.g., of shellfish, due to toxins). The sense of urgency is immediate to understand forces and processes underlying ocean acidification and climate change. In particular, research on threshold CO_2 concentrations that initiate marine organism extinctions is an urgent topic because the viability of some marine organisms is already negatively impacted by increasing CO_2 concentrations in ocean water (Portland workshop).

Research on these topics would address the challenges identified by project participants, which include a lack of specificity in available research findings and difficulty coordinating research efforts:

> ―*…Most [ocean acidification] information [is] given in generalities at this point with somewhat more spatial acuity along the outer coast or from buoy readings...” (Survey Respondent 29).*
>
> *… we have the ability to do the inventory of the species but not to study the effects. We would have to do that through other agencies or through researchers doing that type of work… (California Current Marine #1).*
>
> *...another example of a need is a study of the nutrient loading that is making the pH an issue in the Puget Sound and the impact of climate on the shellfish. New lineages are being created for things like pH which is a climate issue and we are making it worse through nutrient loading in some areas (Puget Sound and Georgia Basin Marine).*

[103] For additional information on contaminants, see Chapter V.1, p. 69. For additional information on monitoring habitat types, see Chapter s VI.1 (p. 89) and VI.3 (p. 112).

The spatial scale in which to focus research and research coordination efforts ranges from the entire North Pacific Ocean for studies to identify thresholds for marine organism extinctions, to near-coastal areas of the NPLCC region for studies of primary productivity, and to the Puget Sound and similar urban watersheds for studies of nutrient loading. Specific research on ocean acidification and food web impacts is also suggested region-wide, but with a focus on the Oregon coast and points northward. A nested approach that includes the major ocean currents (California and Gulf of Alaska Currents) and key subregions of those currents (to be determined) is suggested.

The temporal scale for the identification of thresholds needs to be determined, but the other research topics should include the seasonal component and regularly be updated. For example, investigations of harmful algal blooms should be conducted when it warms right after winter. Data collection should begin immediately to develop a long enough time series to inform management – decades of monitoring and data collection may be needed before useful patterns emerge. Long-term funding and monitoring is also requested.

A number of existing resources and ongoing efforts may provide guidance or assistance with research and research coordination for ocean acidification, hypoxia, phenology, and food web impacts. For example:

- Many U.S. federal agencies and programs within those agencies are addressing the issues identified by project participants. The National Marine Fisheries Service is identifying which commercially and economically important species show a response to reduced pH, including threshold acidification levels at which the response occurs (Levison 2012, p. 18). NASA, the National Science Foundation, and the National Ocean Service are conducting research and modeling (Levison 2012). For more information on federal agencies and programs engaged in ocean acidification work, see Levison (2012).
- The California Current Acidification Network (C-CAN) and the University of Victoria‟s School of Earth and Ocean Sciences currently are coordinating research and outreach efforts in the region. C-CAN is *working to figure out what to do with existing information and what information is needed* including *talking about putting together an information portal, [identifying] what types of monitoring [are] needed for ocean acidification, and then mak[ing] data available to develop models and projections (California Current Marine #2)*
- The University of Victoria has laid a foundation for outreach efforts in the region:

  ―*... The University of Victoria's Ocean and Earth Sciences has developed simple experiments to illustrate lower pH levels in the oceans. We have presented these demonstrations during public events in the Fall of 2011. We hope to duplicate them to school audiences in the field in the spring of 2012. 4. We use research on Blue Carbon to raise public awareness of the crucial role of the ocean as a carbon sink." (Survey Respondent 24)*

- The University of Washington‟s Friday Harbor Labs conducted a macrocosm study that will be useful for understanding food web impacts of ocean acidification and other stressors. Research conducted in 2010, 2011, and other years may be helpful.
- The Northwest Fisheries Science Center, in collaboration with the Climate Impacts Group and University of Washington, is working on algal blooms in the Puget Sound.

There are also a number of other potential partners in the region:

- For physiochemical data and plankton data, potential partners include NOAA‟s Pacific Marine Environmental Laboratory (PMEL), the Northwest Association of Networked Ocean Observing Systems (NANOOS) or other Integrated Ocean Observing System (IOOS), California Cooperative Oceanic Fisheries Investigations (CalCOFI), and Cooperative Zooplankton Dataspace (housed by the Mark Ohman Lab at the Scripps Institution of Oceanography). State, Tribal, and federal co-managers could assist with data collection if funded.
- For food web impacts, one potential partner is Jim Bodkin (U.S. Geological Survey), who studies the population ecology and biology and predatory/prey relations of sea otters (which prey on shellfish vulnerable to the effects of reduced ocean pH).
- For assistance identifying the thresholds for marine organism extinctions, potential partners include NOAA fisheries experts, the Climate Impacts Group, Oregon State University, and Partnerships for Interdisciplinary Studies of Coasts and Oceans (PISCO). PISCO, for example, is conducting research on hypoxic waters, nearshore and offshore acidification, and carbon dioxide budgets. Marine partnerships and natural resource managers may be further sources of assistance.
- For harmful algal blooms, potential partners include citizen science monitoring efforts, local cities, communities, and Tribes. Training would support their own monitoring efforts. Sealaska and commercial industry partnerships may be able to assist as well.

Model ocean conditions, particularly at regional and local scales

Survey respondents isolated several challenges and opportunities with regard to modeling ocean conditions to inform climate change adaptation and resource management efforts for ocean acidification, upwelling, and associated biological and ecological effects. However, modeling ocean conditions was not discussed in the web-based focus groups or workshops. Given the NPLCC‟s goal to identify existing data and research needs and opportunities, and the targeted suggestions provided on this topic, we summarized survey responses below.

Improved regional and local models are the primary focus for the NPLCC region, but global climate models would be needed for reference:

> *—The biggest problem is knowing how physical forcing might change in the future and for this you need global climate models…" (Survey Respondent 41).*

> *—… I would like to know about local or regional climate change models that incorporate nearshore processes like coastal upwelling." (Survey Respondent 55).*

> *Additional tools include —Climate models based at a regional scale or smaller; models that incorporate nearshore processes like coastal upwelling" (Survey Respondent 35).*

Improved regional and local models would respond to a range of challenges observed and experienced by survey respondents:

> *—…Right now their spatial footprint [of global climate models] is rather large, thus they cannot address how things like local upwelling might change. Also only a few models*

have a PDO, which is an important variable. I do not know how well the climate models capture ENSO variability but given that ‗real-time' high resolution models can't get ENSO right, I suppose that GCMs can't get it right either" (Survey Respondent 41).

―*... Downscaling global models is of limited use when addressing the needs of communities associated with coastal watersheds..." (Survey Respondent 55).*

Potential partners include U.S. Geological Survey researchers studying the effect of nutrient sources on biological productivity and predator-prey relationships in the Gulf of Alaska. For example, information on coastal sources and fluxes of iron in the Gulf of Alaska is available from John Crusius. Information on ocean conditions and marine food webs near tidewater glaciers is available from John Piatt and colleagues.

Engage in science communication and outreach with resource managers and the public

Project participants in the Puget Sound and Georgia Basin Marine and California Current Marine #2 web-based focus groups provided two examples of how improved science communication and outreach with managers and the public enhanced climate change adaptation efforts.

In the first example, researchers used climate change scenarios to examine how the pattern of harmful algal blooms in Puget Sound in Washington State may change in the future. They found the HABs may begin up to two months earlier by the end of the century, but managers were concerned with the response for the next season. As a result, the researchers have begun to establish relationships to create a framework that will work for a changing climate. They have *started thinking about how [we] can incorporate climate change into management today* because if there *is a framework already in place they can then incorporate [climate change] in the future…and increase resiliency (Puget Sound and Georgia Basin Marine).*

In the second example, linking climate change to the effects on the shellfish industry generated newspaper articles of interest to the public:

> *For the academic and regulatory community it is great for them to talk but if they are not communicating to the public it is not as potent. For example, Washington has one of the largest shellfish industries in the nation in Willapa Bay…There was some interesting evidence linking acidification and nutrients and linking it to oyster failures…This got in the newspaper and was powerful. [It] linked science to an important partner (shellfish industry) and it got out for the public to see that it is a real and important issue…(California Current Marine #2).*

Both of these examples illustrate that connecting with people, whether they are resource managers or the public, is a key to moving forward on climate change issues. The climate change effects in these two examples were compelling because they were relevant to the audiences‟ needs and interests, and because there was a clear, causal chain linking climate change-related effects to the outcome of concern.

3. Characterize eelgrass and kelp habitats and identify priority areas

Additional information on eelgrass was requested most frequently by web-based focus group participants from British Columbia and was also discussed in the Portland workshop. Eelgrass and kelp beds provide nursery habitat and refuge from predators for many fish and crustacean species of economic or ecologic value (Johnson et al. 2003, Johnson et al. 2010, Penttila 2007, Wright 2002). They are also used by larger species such as sea otters (Maldini et al. 2010). While participants decided to include kelp forests with this topic, kelp forests were only mentioned in the Juneau workshop and were not discussed in detail by any survey respondents or in any web-based focus groups. Climate change-related science and information needs and opportunities for kelp forests remain an area for further discussion. Specific activities discussed in this section include:

- Acquire fundamental knowledge of the physical and ecological processes driving changes in eelgrass distribution
- Study the role of eelgrass and submerged aquatic vegetation in mitigating climate change impacts
- Quantify ecosystem value and services
- Forecast future distribution due to sea-level rise and other drivers
- Improve maps and other geospatial tools to support conservation planning and evaluation
- Improve science communication and outreach with the public and decision makers

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	✓
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	

Acquire fundamental knowledge of the physical and ecological processes driving changes in eelgrass distribution

The most urgent request made by project participants is to acquire fundamental knowledge of the physical and ecological processes driving change in eelgrass distribution.[104] This information would be used to

[104] Project participants represented are those from the Portland workshop and the British Columbia Coastal Marine, Puget Sound and Georgia Basin Marine, and California Current #1 web-based focus groups.

interpret decadal trends, understand abrupt collapses in eelgrass communities, understand the relative competitive ability of native and exotic eelgrass species, and project future distributions. Baseline data, including temperature and salinity data, is a focus throughout British Columbia because *it is difficult to see changes if you don't have a baseline (Puget Sound and Georgia Basin Marine).* For example, on the North Coast of British Columbia:

> *Offering a northern perspective – we are facing a different issue and that is an understanding of the way that it (eelgrass) grows and its particular vulnerability for our region. We are a few steps back because we are not sure if the impacts will be the same for our region as in other regions. An interesting study looks at the relation between sedimentation and eelgrass and how changes in sedimentation will impact the eelgrass (British Columbia Coast Marine).*

Improved understanding of the ecological system, in turn, would inform local planning and permitting processes and conservation practice. The spatial scale for research varies from site-specific studies to better understand physical and ecological mechanisms to embayment and watershed assessments:

> *… ecosystems like intertidal tide flats and eelgrass would probably be the two primary types of spatial changes within estuaries that we would be interested in for managing those [fishery] species. That is really the only active management. What we don't have are the process data, what would it mean and what are the types of climate change impacts and their potential impacts on species and habitats?... (California Current Marine #1)*

Partners in this effort could include existing eelgrass stressor programs, as well as tribal, state, and federal agencies.

Study the role of eelgrass and submerged aquatic vegetation in mitigating climate change impacts

Participants observed that eelgrass provides a number of services for coastal ecosystems including wave and erosion dampening, sediment retention, and carbon sequestration. Web-based focus group and workshop participants indicated a better understanding of the role of eelgrass in these processes would be beneficial:

> *Eelgrass is particularly interesting because it is also a mitigation tool through carbon sequestration… One example of this is coring data where we can date the plants and figure out sequestration potential… (British Columbia Coast Marine).*

The spatial scale varies from the embayment to NPLCC-wide. Urgency is listed as "moderate," to be completed in the next five to ten years. Finally, given the relationship between the sediment regime and carbon sequestration potential, the information in Chapter VI.1 (p. 89) on sediment accretion, subsidence, flux, and transport would also inform studies of the role of eelgrass and submerged aquatic vegetation in mitigating climate change impacts.

Quantify ecosystem value and services

Portland workshop participants suggested linking the ecological and economic value of eelgrass specifically in terms of interactions between land use, services, and food would raise human community support for protection and elucidate the benefits and consequences of a business-as-usual approach:

> *…Another question is the possibility of using it as an economic level for offsetting carbon (British Columbia Coast Marine).*

To provide local relevance and a larger context, the spatial scale should vary from a nested watershed to NPLCC-wide scale. State agencies, tribes such as the Tulalip Indian Tribes, and federal agencies including NOAA, USGS, and EPA were listed as potential partners.

Forecast future distribution due to sea-level rise and other drivers

Workshop participants indicated that acquiring the ability to estimate future distribution in light of sea-level rise and other stressors would help guide and prioritize areas for restoration and management. For example, participants stated it would help ensure migratory corridors were available for birds and habitat availability for fish that depend on eelgrass for forage, nursery, and prey:

> *…knowledge of the vulnerable habitats, clearly beaches and inland eelgrass beds etc. where are the habitats that we will lose and are there migration corridors?...To include corridors, biogeographic hot spots, vulnerable populations….maps of where we need to be concerned with sea level rise….lists of species that are going to be impacted (California Current Marine #2).*

Participants observed that the spatial scale to focus estimates of future eelgrass distribution would depend on the corridor-requiring species (e.g., birds, salmon), but could include the local, embayment, or NPLCC (corridor) scale. Since other information is needed first, workshop participants requested estimates of future eelgrass distribution in five to ten years. Watershed groups, state agencies, and federal agencies were cited as potential partners.

Improve maps and other geospatial tools to support conservation planning and evaluation

Both workshop and web-based focus group participants identified baseline mapping data as an urgent underfunded gap to address in order to facilitate monitoring change:

> *[We are] heavily involved in eelgrass – we have no baseline data to look at eelgrass. It is up to non profits to fund the mapping…so it makes no sense that they can't get funds from federal sources for this type of work… (Puget Sound and Georgia Basin Marine).*

At the watershed scale, participants requested data at the annual to multi-year temporal scale, while decadal data was requested at the NPLCC-scale in order to track climate impacts. Marine resource councils and state agencies were identified as potential partners. Workshop participants suggested that combining the two scales would facilitate coordination of on-going efforts at smaller scales and would help guide fish management plans, coastal and marine spatial planning, and marine protected area decisions. Overall, mapping capacity would refine the current approach to restoration, help identify priority areas for conservation, and would be an input to restoration performance assessments:

> *…Much of the decision making is focusing on trying not to destroy the eelgrass or make up for the fact that you are destroying it… Like [a participant from British Columbia] the climate change modeling needs to indicate the best areas to compensate or preserve eelgrass. For this we need region-specific information. We need more than just a no net loss policy… Maybe down the road looking at sequestration instead of no net loss… (British Columbia Coast Marine).*

In addition to mapping, Juneau workshop participants suggested development of a geospatially based tool to identify vulnerable habitats and landscapes such as watersheds, kelp beds, and drought areas. The tool should be designed with a particular objective and audience in mind. It could help identify watersheds for more intensive monitoring or research, habitats for restoration of salmon and other species, and community-based hydropower projects. The tool should be supported by a geospatial data platform and utilize 6-field HUC. Since several years will be needed to develop the tool and significant time will be needed to maintain the tool, workshop participants suggested starting with a challenging project site and working with indigenous communities to select an appropriate spatial and temporal scale for the project.

Several ongoing efforts and potential partners may be able to assist with the development and implementation of this tool:

- The Natural Capital Project‟s Integrated Valuation of Environmental Services and Tradeoffs (InVEST) tool (Juneau workshop).
- Steve Paustian with the U.S. Forest Service, Tongass National Forest, out of Sitka (Juneau workshop).
- Results from the Alaska Coastal Rainforest Center‟s data integration workshops (Juneau workshop).
- Colin Beier at State University of New York College of Environmental Science and Forestry (SUNY ESF) is conducting vulnerability mapping for watersheds and may be able to assist as well (Juneau workshop).

Improve science communication and outreach with the public and decision makers

Web-based focus group participants from British Columbia and the Puget Sound identified effective engagement with the public and decision makers as a significant challenge. For example, *it makes no sense that [nonprofits and others] can't get funds from federal sources for [baseline data and mapping of Eelgrass] (Puget Sound and Georgia Basin Marine).*To address the challenge, communication and outreach at multiple levels was suggested, from the local and community level to port authorities, provincial agencies, and federal agencies:

> *…There is also a need to engage the local level, community level, port authority etc to see impacts…Engaging the correct decision making bodies continues to be a challenge. We would like to see increased action from certain agencies in BC (British Columbia Coastal Marine).*

4. Inform cost estimates and vulnerability assessments related to altered coastal flooding regimes in Puget Sound and the California Current Region

Participants in the Puget Sound and Georgia Basin Freshwater and California Current Marine #1 web-based focus groups, the Portland workshop, and several survey respondents discussed the usefulness of generating research results and maps that inform cost estimates and vulnerability assessments for ecological and economic resources likely to be affected by altered coastal flooding regimes. Specific activities suggested for coastal flooding regimes are:

- Model and map inundation regimes and associated habitat changes
- Estimate ecological and economic costs
- Improve science communication with the public and decision makers

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	✓
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	✓
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	
Arcata Workshop	

Model and map inundation regimes and associated habitat changes

This activity area was identified by participants in the California Current Marine #1 web-based focus group, the Portland workshop, and three survey respondents. To model and map inundation regimes, Portland workshop participants suggested acquiring baseline data on LiDAR, current tides, extreme events such as floods, changes in interannual variability, and other factors to inform decisions affecting infrastructure, emergency management, land use, and habitats. The baseline data would improve climate change projections and models of predicted fluvial and tidal inundation regimes that account for the region‟s unique hydrologic regimes (California Current #1, Portland workshop). In turn, the baseline data and models could assist efforts to ―*…prepare coastal flooding maps at various scales for the state, for a range of future sea level rise scenarios, different tidal data, and various storm surge and river flow conditions…" (Survey Respondent 33, also see p. 2 of California Coastal Commission, 2008*) and identify ―*…conservation opportunities for shoreline and coastal salt marsh areas…" (Survey Respondent 12)* such as wetlands that have the opportunity to migrate. To further support identification of conservation opportunities, baseline data, models, and maps could be used to determine conservation criteria and as inputs to tools that ―*…identify hazard zones in developed areas, encourage retreat, and restore areas to a ‗natural' shoreline…" (Survey Respondent 12).*

For example, in the Pacific Northwest, *there is a connection between river flows and tides and estuaries that [will] have a huge effect on inundation regime effects in the future* due to the region‟s *very flashy systems, very event-driven sediment regimes*, and *inundation regimes [that] are strongly seasonal* (California Current Marine #1). This means developing region-specific models and paying close attention to data input and parameterization, as well as making use of existing maps or sea-level rise viewer tools:

> *We need models of predicted combined fluvial/tidal inundation for our estuaries. The models need to be spatially and temporally explicit since inundation regimes are strongly seasonal. Examples: Brophy 2009, Brophy et al. 2011, Huang et al. 2011 (California Current Marine #1).*
>
> *…the data input and the parameterization of input makes such a huge difference in the outcome…Can't take a model from one part of the country and assume that it will work for our area…[useful tools are] based off of scale and the way that it is parameterized (California Current Marine #1).*
>
> Existing tools include ―*…inundation maps or sea level rise viewer tools where available…" (Survey Respondent 29).*

The suggested spatial scale for models is the NPLCC region‟s coastline including Puget Sound; the temporal scale includes seasonal data with additional information on extreme events, as well as historic data and future modeling. Developing partnerships at the local government level is suggested, as is developing partnerships in the transportation sector, state agencies, and federal agencies. For example, the USGS Pacific Coastal and Marine Science Center‟s Southern California Coastal Hazards program has high-resolution digital elevation models, a spectral wave model, and a model prediction system that includes a tide model, the Coastal Storm Modelling System (CoSMoS), a surge model, and other models. They are currently applying CoSMoS to the entire California coast and have plans to expand to Washington and Oregon as well. There is also a Sea Level Rise and Coastal Flooding Impacts Viewer available from Digital Coast, a NOAA Coastal Services Center decision-support system.

Estimate ecological and economic costs

Two survey respondents and participants in the Puget Sound and Georgia Basin Freshwater web-based focus group suggested estimating the ecological and economic costs associated with altered coastal flooding regimes. This information would assist efforts to update armoring permitting processes and could help identify ―*…ways to increase fiscal and other incentives for shoreline property retreat and for ‗soft' flood and erosion protection solutions…" (Survey Respondent 12).* While cost estimates for flooded infrastructure and other "usual suspects" in the built environment were suggested, there was a greater emphasis on ecological costs to the ecosystem and habitats:

> *What hasn't been done is looking at ecological impacts of coastal flooding and I wonder if that's another priority to pledge in the mix. With flood risk we typically look at what communities and structures are at risk, but coastal and nearshore freshwater habitats, in*

what ways are they at risk? Maybe transitioning from fresh to saltwater or getting squeezed between flood protection works and rising seas. (Puget Sound and Georgia Basin Freshwater)

Specific suggestions for cost estimates include a full valuation of the costs and benefits to coastal ecosystems and associated tools for determining costs and benefits of shoreline ecosystem services (Survey Respondent 12). In the built environment, Survey Respondent 29 suggested amortized cost estimates of land use changes relative to engineered solutions over fifty to one hundred years, including estimates for *moving houses back from the shoreline relative to higher and stronger seawalls and bulkheads at the individual property scale and for local jurisdictions…" (Survey Respondent 29).*

Improve science communication with the public and decision makers

The Puget Sound and Georgia Basin Freshwater web-based focus group discussed two items related to science communication with the public and decision makers. The first item pertains to overcoming challenges associated with communicating the impacts of sea-level rise on the nearshore environment to support a proactive response:

> *The other need, which is more of a sociological aspect, has to do with being able to communicate what the impacts of sea-level rise are going to be on nearshore environments – what those impacts are going to be, how to plan for it, and how to adapt to it…One of the things that we think will be important is that effects of sea-level rise will be compounded with events…Within days of event, they'll claim emergency and build armoring higher to protect infrastructure. How are we going to deal with that from a social standpoint in terms of response and mitigation for those events when it's not slow and steady sea-level rise but the events? (Puget Sound and Georgia Basin Freshwater).*

Participants from the Fraser River Delta provided an example of an existing approach that has been effective for creating and sustaining a dialogue with the community. The local government is using visualization tools *to look at a range of options from raising dikes to a higher elevation to managing retreat* and examining areas susceptible to flooding within the current redevelopment cycle *(Puget Sound and Georgia Basin Freshwater).*

VII. Activity Areas for Terrestrial Ecosystems and Habitats

The most frequently discussed terrestrial ecosystems were coastal temperate rainforests. More than their aquatic counterparts, project participants working in terrestrial ecosystems emphasized the importance of working across ecosystems and viewing the NPLCC region as an integrated terrestrial-marine-freshwater system:

> *I think the LCC could make a huge contribution is leading the science planning that identifies some of the linkages between these cross-boundary ecosystems like terrestrial, aquatic, coastal, marine… (Coastal Temperate Rainforest Ecosystem).*

In fact, it was soil hydrologists and others working at the nexus of terrestrial and freshwater ecosystems that suggested modeling freshwater duration, temperature, and flow across the landscape (see Chapter V.1, p. 69). Project participants identified the NPLCC as a historic and current dispersal corridor in which wanted and unwanted species have long migrated, particularly along the north-south gradient, and will continue to do so. They therefore focused their discussion on science and decision-support projects and activities at the landscape-level, especially along the NPLCC"s north-south gradient.[105] Particularly in the southern portions of the NPLCC region and the Kenai Peninsula in southcentral Alaska, project participants also focused on sources of disturbance that are currently important in one area and may migrate to another such as pathogens and fire moving northward or westward. In southcentral Alaska, for example, interactions between fire regimes and spruce bark beetle are an active area of research. Fire is covered in this chapter, while information on pathogens such as bark beetle is covered in Chapter IX (p. 166).

The primary challenges cited by project participants working in terrestrial ecosystems were keeping up with the latest scientific information, dealing with conflicting research results, inability to assess the quality of research from different fields, competition between addressing current and future stressors, and a lack of actionable level information:

> *Keeping up with the science is a challenge... so much coming out every day, in many forms and with variation in the scientific rigor applied (Survey Respondent 66).*

> One challenge is*…the difficulty of choosing between triage of immediate stressors and risks to conservation compared to possible future climate effects. Investment in one of these choices reduces our ability to address the other. Biggest challenge remains the need for actionable level information and analyses, particularly best available downscaling and scenario planning that works for landowners, managers, communities, and conservation agencies (Survey Respondent 78).*

> Challenges include: *So many unknowns [and] conflicting research results that show far different responses by wildlife and systems to climate change (Survey Respondent 71).*

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[105] East-west gradients and upslope-downslope gradients received less attention from project participants than the north-south gradients.

The activity areas for terrestrial ecosystems and habitats are:

1. Address climate change effects on large landscapes, especially whole-scale changes in vegetation composition
2. Increase the resiliency of connectivity and refugia networks to climate change effects
3. Study the interaction of fire with other disturbance regimes given current and potential future climate change effects
4. More and better coordinated assessments of climate change effects on fog patterns and forest hydrology in northwestern California
5. Support to advance efforts to address climate change in the Willamette Valley, Oregon

Within an activity area, several specific activities requested by project participants are described. The description includes information on how many project participants identified the activity and the climate change-related challenges associated with pursuing the activity. To provide information to the NPLCC about when, where, and under what circumstances support is requested, participant evaluations of the activity across the four evaluation criteria are synthesized:

- *Decision-relevance* indicates which decisions the activity would help inform or guide.
- *Timeline or sense of urgency* indicates when the activity is needed and provides a sense of why and how important, or urgent, it is to pursue the activity.
- *Spatial and temporal scale* identifies the necessary geographic region or spatial coverage for the activity and whether the activity is needed on an annual, seasonal, daily, etc. timescale.
- *Partners and ongoing efforts* identifies the people, partnerships, and organizations that might already have information about the activity or might be well suited to develop it.

1. Address climate change effects on large landscapes, especially whole-scale changes in vegetation composition

Project participants from throughout the NPLCC region requested documenting and addressing whole-scale landscape change in response to current and projected effects of climate change. Suggestions ranged from developing models and scenarios of landscape-level changes in vegetation composition to identifying priority watersheds in which to monitor large-scale changes and characterizing changes in tidal swamp ecosystems (see Chapter VI.1, p. 89 for more information on the latter). The first two suggestions are discussed in this section, along with a number of research and decision-support projects and activities:

- Study climate change effects on soils, plant species, and phenology
- Project changing distribution of trees and vegetation under different management options using maps and models
- Assess and monitor responses of wildlife habitat, vegetation, nutrients, and food availability to climate change effects
- Develop scenarios for change in vegetation composition and structure in priority areas
- Assess the vulnerability of cedar, especially yellow-cedar, to climate change effects

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	✓
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	✓
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	✓
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	
Juneau Workshop	✓
Arcata Workshop	

Study climate change effects on soils, plant species, and phenology

Project participants identified basic research on climate change effects on soils, plant species, and phenology as key components to develop sound predictive models of plant species response to climate change, enhance climatic envelope modeling, and inform active management of priority species (Juneau workshop). Specific requests include:

- *―I need to conduct more experiments to evaluate the sensitivity of soils to temperature and precipitation changes over time" (Survey Respondent 59).*
- Acquire a solid understanding of the impacts of climate change on plant species including base maps for use with climate envelopes (Juneau workshop).

- Acquire phenology data on important plant species including forage plants, critical culturally significant plants, pollination timing, and loss of canopy by leaf fall (Lowlands, Prairies, and Other Non-forested Systems, Juneau workshop).

Project participants stated the need for this information is "high." Since it will take time to collect, analyze, and synthesize information, project participants suggest beginning immediately (Juneau workshop).

The spatial scale could extend throughout the NPLCC for information on plant species, but southcentral and southeast Alaska were identified as of unique importance given the region"s glacial history, soil drainage dynamics, and productivity issues (Juneau workshop). For example, in recently deglaciated areas, ecosystem change and succession can be studied as it occurs. For information on phenology, the spatial scale should extend LCC-wide, with a focus on British Columbia and southcentral and southeast Alaska for culturally significant plants (Juneau workshop). For culturally significant plants, it is suggested that village elders be consulted to determine the appropriate spatial scale (Juneau workshop). The spatial extent would be determined by the distance animals travel to forage and identification of priority habitats (Juneau workshop).

The temporal scale focuses on producing baseline information that can be used to model 200 years into the future, as well as enabling long-term monitoring over the next 100 years (Juneau workshop).

The NPLCC was suggested as a key partner to bring together other partners and stakeholders (e.g., agencies, university researchers, indigenous communities), and to facilitate collecting, coordinating and sharing of phenology information (Lowlands, Prairies, and Other Non-forested Systems, Juneau workshop). Project Budburst may be a potential ongoing effort of interest because they are already collecting basic phenology information through citizen science efforts. For specific assistance with carbon sequestration in forests, David D"Amore (U.S. Forest Service, Pacific Northwest Research Station) was suggested as a potential partner.

Project changing distribution of trees and vegetation under different management options using maps and models

Current climate change effects cannot be fully understood without the context of long-term climate influence on the origins and migration history of tree species (Juneau workshop). Project participants identified information on past, current, and potential future distributions of trees and vegetation as a topic for further study in the NPLCC region (Alaska and British Columbia Coast Freshwater, Juneau workshop). In addition to providing the long-term context in which to consider current climate change effects, this information would inform management and development plans in important and potentially shifting habitats (Juneau workshop).

The most urgent request in the NPLCC region related to this activity is LCC-wide species distribution models for use in climate models, specifically climate envelopes that capture 10,000 years of information (Juneau workshop). This request was made by project participants discussing international and institutional cross-boundary issues the NPLCC could help address (Juneau workshop). Specific species to focus on include western red cedar and yellow-cedar (Juneau workshop). Ecologists and paleoecologists from Canada and the U.S. are potential partners in these modeling efforts.

To inform management and development plans, distribution information should include three types of information:

- The occurrence, origins, and migrations of species in the paleorecord
- High-resolution imagery of the current distribution in the NPLCC region, available in a synthesis format
- Future projections of distribution given climate models

Distribution information could then incorporate and inform changes in vegetation response due to management of young-growth and old-growth forests:

> *[One need for old-growth is to] identify kinds of vegetation communities and changes to those communities – type of vegetation in the future and understanding the species vulnerabilities (Alaska and British Columbia Coast Freshwater).*

Finally, distribution information that is available in a visual format will depend on data inputs such as GIS layers. In southcentral and southeast Alaska where much of this work was suggested, acquiring basic GIS layers would reduce the need for extrapolation and improve data availability and quality:

> *I think one thing that the LCC could do some value-added is develop some basic GIS information. There are a lot of areas especially in Canada and adjacent Tongass National Forest where we just don't have good vegetation or watershed data for good solid land types or GIS coverage. That puts us in a position of having to suppose the outcome of climate change scenarios based on extrapolations. Some areas where we work and manage a lot, we have really good data, but there is a broad area where we don't have data. I am especially interested in water dynamics in that context, but also just the basic vegetation cover and that sort of physioecology (Coastal Temperate Rainforest Ecosystems).*

The spatial scale for the distribution and modeling requests includes the entire NPLCC region, but should be organized according to management or planning units such as national forests and parks (Juneau workshop). Maps in Alaska were specifically requested because current maps are inadequate (Juneau workshop). The temporal scale for distribution and modeling activities should capture the immediate response of vegetation management as well as the response of long-term, old-growth development. Potential partners include the U.S. Forest Service, Sealaska, Geos Institute, states, provinces, and the National Park Service. For example, the Geos Institute and partners used three GCMs, climate envelope models, and functional vegetation model to project changes in the distribution of rainforest assemblages and thirteen focal species, identify potential climate refugia, and map changes in ecological processes such as wildlife dynamics and carbon storage in vegetation. Changes were projected for two time periods (2040-2069, 2070-2099) under the A2A and A1B emissions scenarios compared to a 1950-2000 baseline. Of the thirteen focal species, eight are commercial conifers found in the temperate rainforest region (Sitka spruce, western and mountain hemlock, western redcedar, Alaska yellow-cedar, Pacific silver and grand fir, and coast redwood) and two are epiphytic lichens (witch's hair, *Alectoria sarmentosa*; lettuce lichen, *Lobaria oregano*). The remaining three focal species are bird and mammal species (see Chapter VIII.3, p. 160; DellaSala et al. *in review*).

Assess and monitor responses of wildlife habitat, vegetation, nutrients, and food availability to climate change effects

Participants in the Juneau workshop suggested research and other activities to investigate, inventory, and monitor responses of wildlife habitat, vegetation, nutrients, and food availability to climate change effects. As vegetation communities shift, coupled with changes in climate and food availability, it will be helpful to understand the changes and be able to manage into future (Juneau workshop). This includes information on successional changes in vegetation, genetic conservation of species, and interactions between habitat changes and species response such as alterations in deer range to variation in snow depth. The information would inform ecological planning, specific adaptive management strategies, and restoration capacity over time (Juneau workshop).

Project participants suggested several specific activities to acquire this information. These include:

- To ensure well-distributed viable populations, ecological planning and adaptive management strategies could include monitoring of habitat response to timber harvest, young-growth management, and silviculture (Juneau workshop).
- To support genetic conservation of species, develop an inventory of genetic reserves and begin to collect missing species (Juneau workshop).
- To understand and model successional changes due to climate change, utilize current species distribution maps (Juneau workshop). For more information on these maps, please see the previous sub-section.
- To understand the transport and contribution of forest borne nutrients to coastal ecosystems and their effects on nearshore productivity, conduct research and monitoring at key watershed reference sites (Juneau workshop).

The spatial and temporal scale varies by activity. For changes in vegetation communities (e.g., successional changes) and the response of species, the spatial scale should include the range of individual species populations and information should be available at the scale of planning in national parks and forests (Juneau workshop). Similar to the previous sub-section, the temporal scale for should capture the immediate response of vegetation management as well as the response of long-term, old-growth development (Juneau workshop). For genetic conservation, a NPLCC-wide effort over the next three to five years is "fairly urgent" (Juneau workshop).

Potential partners include the U.S. Forest Service, the U.S. National Park Service, U.S. Fish and Wildlife Service, Sealaska, states, and provinces. For specific assistance with nutrient contributions from forests, Rick Edwards (U.S. Forest Service, Pacific Northwest Research Station) was suggested as a potential partner. For genetic conservation of species in particular, the National Seed Library and National Genetic Engineering Lab (NEGEL) were suggested as potential partners.

Develop scenarios for change in vegetation composition and structure in priority areas

Project participants suggested ―*g*neration *of scenarios for change in vegetation composition and structure resulting from natural environmental and human-caused change" (Survey Respondent 69).*

Scenarios would respond to some of the challenges cited for the region including a lack of specific information to use in planning and decision making:

> *―[There is] insufficient specific information to use in planning and decision making. If we can't tell a District Ranger what the effects are likely to be, they can't make decisions. Currently we aren't even touching this need…[There is also a] complete lack of scenario planning with the exception of work done by the City and Borough of Juneau in 2006" (Survey Respondent 36).*

Scenarios could inform a range of decisions including land management planning and vegetation management, as well as inform the public. In southcentral Alaska for example:

> *―.Results of [scenarios] could support land management planning and project development by putting boundaries on desired conditions (quantifying expected ranges of variability), aiding in the prediction of outcomes of vegetation management, and informing the public regarding expectations for the future of southcentral Alaska ecosystems" (Survey Respondent 69).*

Given limited resources and capacity, identifying priority areas to document whole-scale landscape change was suggested:

- *We need to look at key watersheds. They are looking for multiple ecological processes and are trying to make it more comprehensive than just old growth (Alaska and British Columbia Coast Freshwater).*
- *In British Columbia…[the] next priority is better coverage on future hydrologic scenarios. [We] may not have resources to do this across various watersheds all across the province. Could we identify representative sites and treat as reference watersheds and run some scenarios for future times in these watersheds? (Puget Sound and Georgia Basin Freshwater)*
- Identify locations of biome change and latitudinal shifts (Juneau workshop).

One survey respondent suggested scenarios should include information on climate change and other sources of disturbance. Participants in the Juneau workshop echoed several of the suggestions:

- *―.Environmental variables affecting change to be considered would include (but are not limited to): climate change, fire, wind throw, avalanches, landslides, flooding, tectonics, insects, disease, and natural succession. Human changes include management treatments and user impacts…" (Survey Respondent 69).*
- Changes in the intensity and duration of extreme weather events such as snow depth and duration (Juneau workshop).
- Changes in disturbance that affects structural diversity across NPLCC (Juneau workshop).

The spatial scale for scenarios should include two to four levels of spatial resolution (Survey Respondent 69). Potential partners include federal agencies such as USGS, U.S. FWS, and the U.S. Forest Service, universities, and research scientists engaged in developing models and scenarios of vegetation change (Survey Respondent 69). Specific research scientists suggested as potential partners include:

- Ron Neilson (U.S. Forest Service, Pacific Northwest Research Station) is a bioclimatologist who has published on forest processes and global environmental change, climate change effects on vegetation distribution and carbon budget in U.S. ecosystems, and use of the MC1 model to estimate the distribution of vegetation and associated ecosystem fluxes of carbon, nutrients, and water.
- Glen Juday (University of Alaska Fairbanks) is a forest ecologist who studies climate change and forest growth, climate change assessment, and fire and climate change. Research projects include the responses of Pacific Northwest and Alaska forest to multiple environmental changes and the relationship of tree growth and climate variability in Alaska.
- Mike Goldstein (U.S. Forest Service) has studied coastal temperate forest ecology and wildlife ecology in the NPLCC region.

Assess the vulnerability of cedar, especially yellow-cedar, to climate change effects

Information on the vulnerability of cedar, particularly yellow-cedar, to climate change effects was discussed during the Juneau workshop. To assess vulnerability, specific requests include:

- Current intensity and extent of yellow-cedar mortality
- Loss of yellow-cedar as a cultural resource
- Successional changes following cedar decline
- Future forecasts of cedar decline
- Models that include a high-resolution species distribution sub-model for cedar, snow dynamics (a risk factor for mortality), and hydrology dynamics (a finer scale risk factor for mortality).

This information would inform climate change adaptation strategies, which in turn would inform forest conservation management plans and specific tactics to provide viable cedar populations such as deciding "where to favor cedar by planting and thinning" (Juneau workshop). For yellow-cedar in particular, acquiring knowledge for resource planning is urgent because yellow-cedar is extremely valuable as a cultural resource, as well as for timber and forest ecology (Juneau workshop). This type of information would also address questions about how landscapes are changing, what landscapes will look like in the future, and what actions can be taken now to help landscapes transition and maintain or improve resilience. For example:

> *Sometimes we have a question about when something is environmentally sensitive, not as a traditional endangered species or something like that but an area that is valuable for another reason. With climate change there are areas that are becoming more valuable than in the past. Vegetation types that are on the southern extent of a range of a particular type of habitat or ecological community…[may be] more valuable because it is at the southern extent of the range due to genetic information but it might not be listed. We are looking to better define and identify areas that might be more sensitive (California Current Marine #2).*

The spatial scale should extend at least the 1,000 km in British Columbia and Alaska where yellow-cedar decline is observed currently. The temporal scale should extend from a 100-year backcast to 100 years in the future.

In Alaska, potential partners include the U.S. Forest Service‟s National Forests and Pacific Northwest Research Station, national parks, Sealaska, and Native communities. In British Columbia, potential partners include the University of British Columbia, the Ministry of Forests, Lands, and Natural Resource Operations, and Cowichan Lake Research Station, which is part of the Ministry‟s Forest Genetics Section. In Washington and Oregon, potential partners include the U.S. Forest Service‟s National Forests and Pacific Northwest Research Station. Across the region, the NPLCC could help facilitate knowledge exchange and comparison (primarily latitude and elevation differences in yellow-cedar distribution and mortality) in Alaska and British Columbia, as well as incorporating science with Traditional Ecological Knowledge (Juneau workshop).

2. Identify, protect, and maintain the integrity of connectivity and refugia networks in light of climate change effects

Refugia and connectivity were discussed frequently in the terrestrial web-based focus groups and the workshops held in Juneau and Arcata. Participants noted the NPLCC"s large north-south gradient has long been a pathway for species migrations and dispersal and is therefore a potential resource to understand and respond to current and potential future species and habitat migrations:

> *One really important thing the LCC provides is that it spans such great latitude and is a pathway of migration of plants and other organisms from southern environments up into our area. Many of the species that are currently in southcentral Alaska coastal areas came, based on the paleorecord, up the coast through the LCC. I would expect a fair bit of that might happen in the future. I think it's going to be a pretty useful perspective on what's going on throughout the whole LCC (Coastal Temperate Rainforest Ecosystem).*

> *One potential workshop topic that the LCC is already working on is habitat connectivity. That would an obvious one that cuts across a variety of land ownerships (Interior Mountain Ecosystems).*

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	✓
California Current #1	
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	✓
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	✓
In-person Workshops	
Portland Workshop	
Juneau Workshop	✓
Arcata Workshop	✓

The activities identified for refugia and connectivity are:

- Improve data availability and integration
- Conduct research and climate change vulnerability assessments on the biodiversity and ecology of island ecosystems
- Evaluate the strengths, limitations, and opportunities for the current network of refugia, corridors, and reserves to be resilient to climate change effects

Improve data availability and integration

Project participants, particularly those working in Alaska, British Columbia, and Washington, requested efforts to improve cross-boundary data availability and integration. In some cases, data is difficult to access due to institutional rules or difficult to use due to different measuring systems:

> *A real challenge has been, when we think about connectivity and certainly when we get across international borders but even state borders, of just knowing what data is available and how we make that a little more seamless (Interior Mountain Ecosystems).*

> *With British Columbia right now, I know there are quite a few where the data doesn't line up or it's just not available on the other side of the border (Interior Mountain Ecosystems).*

Participants stated that the NPLCC"s organizational structure makes it well-suited to assisting with improving cross-boundary data availability and integration:

> *Certainly the LCCs have a role there working across these borders, providing not only what data is available but different scales that are applicable to looking at these issues or having the connections that can help us understand that question (Interior Mountain Ecosystems).*

Shared and integrated datasets would enable and inform identification of refugia and corridors. An understanding of the past and current movement of species and habitats would also inform specific planning processes such as the Chugach National Forest"s current planning effort (Coastal Temperate Rainforest Ecosystem).

The spatial scale would focus on political boundaries between states and countries, as well as integrating data from multiple land owners:

> *What data do I have to work with [in BC and WA]? …not just on public lands where that's easy to find, but is there any available data on tribal and private lands that we can…have access to? Or a listing of who can get access or how you would get it or establish a process to get it? (Interior Mountain Ecosystems).*

The temporal scale would include the paleorecord, as well as current and future data:

> *Someone mentioned earlier the importance of the paleoecological record and I would certainly reiterate that I would hope that is a part of the analysis that goes on with this effort – information on what happened with past climate changes (Coastal Temperate Rainforest Ecosystem).*

Potential partners include the Alaska Coastal Rainforest Center and the Washington Habitat Connectivity Working Group, both of which are working actively on this issue. Project participants suggested building from the existing data integration workshops convened by the Alaska Coastal Rainforest Center and partners.

Conduct research and climate change vulnerability assessments on the biodiversity and ecology of island ecosystems

The island ecosystems of southeast Alaska are naturally fragmented systems characterized by high endemism and genetic diversity, but in many cases relatively low species diversity (Cook et al. 2006, Juneau workshop). Island ecosystems were a discussion topic in the Juneau workshop. Web-based focus group participants from Alaska also discussed the unique climate-induced stressors to these systems:

> *…in an island archipelago like we have here or even with mainland areas that are often isolated as habitat islands even though they're fairly big, we would anticipate that there are going to be some kinds of vegetation changes that might be somewhat special or unique or have new kinds of issues. For example, on islands that have alpine habitat right now and potentially have endemic species or even non-endemic species, to what degree is that alpine habitat going to disappear as forest cover moves upslope? (Coastal Temperate Rainforest Ecosystem).*
>
> *I believe that within at least southeast Alaska and island archipelagos, we are looking at some significant changes that are going to occur over the next century, not over the next millennium (Coastal Temperate Rainforest Ecosystem).*

Participants also noted the climate-related challenges and opportunities in island ecosystems are applicable to other fragmented systems such as those separated by large areas of ice in Alaska and British Columbia or isolated peninsular systems (e.g., Olympic National Park and Forest in Washington). Several specific potential research and decision-support activities were identified for this activity area:

- Characterize North Pacific biotic diversity including mammals, birds, amphibians, and plants. The southeast Alaska archipelago system represents very high genetic diversity for many taxa as a result of repeated glacial events and effects of island and other natural fragmented system dynamics (Cook et al. 2006, Juneau workshop). Information is requested immediately on less agile species, those with risk of extinction, or species subject to climate change, development or disaster effects. Information on biodiversity is requested within the next 10-20 years.
- Investigate the evolutionary and ecological dynamics of nearshore archipelago ecosystems such as southeast Alaska‟s. This is in addition to existing efforts to inventory species because *if you don't understand some of the important ecological relationships that are obligate or dependent, then you really won't understand some of the impacts occurring within the community or across the entire community (Coastal Temperate Rainforest Ecosystem).* These dynamics will impact restoration, the maintenance of Subsistence systems, forest management decisions, and other development decisions. It will also impact harvest decisions (hunting, etc) and control of invasive species and disease. For example, how is chytrid fungus impacting potentially endemic and isolated populations of boreal toads?
- On monthly to yearly timescale, determine the vulnerability of key island species to climate change, including barriers to range shifts, the likelihood of habitat losses given definitive barriers to migration, susceptibility or protection from invasive species or disease, and the distribution of critical endemic species and habitats. This would guide decisions as to where conservation resources should be allocated, (e.g., protected areas, assisted migration, or invasive control).

Participants suggest using niche theory, monitoring, and traditional ecological knowledge in assessments and stated that vulnerability information is an operational activity and may not be among the most urgent compared to the other requests.

- Document traditional species or cultural uses to investigate how changes to species diversity may directly impact cultural diversity. For example, the presence of brown bears only on Admiralty, Baranof, and Chichagof Islands might impact cultural diversity across southeast Alaska.
- Monitor broad areas of ecosystem performance over time to assist identification of vulnerability hotspots, which in turn aids potential triage decisions about where to carry out adaptation actions to address the most vulnerable species, habitats, and locations.

These research and decision-support activities are similar to those described for rare, endemic, vulnerable, and keystone species throughout the NPLCC region (see Chapter VIII, p. 149). For example, there is an emphasis on understanding evolutionary and ecological dynamics, as well as identifying focal or keystone species. This suggests the activities suggested for rare and endemic species and habitats are relevant across the NPLCC region as well as within vulnerable ecosystems such as the island ecosystems discussed here.

The spatial scale in which to focus these activities is the entire NPLCC, with an emphasis on island archipelagos and fragmented regions using nested scales to account for insular and proximity effects in archipelagos. The primary spatial focus would be southeast Alaska (e.g., Tongass National Forest), but case studies of the San Juan Islands in Washington and Broughton Archipelago in British Columbia should be used for comparison and contrast to inform decision making.

For assistance with characterization of biodiversity and investigation of ecological and evolutionary dynamics, the following people are suggested:

- Joe Cook and Steve MacDonald with the University of New Mexico Museum of Southwestern Biology, Mammal Division
- Winston Smith (University of Alaska Fairbanks Institute of Arctic Biology)
- Natalie Dawson (The Wilderness Institute at University of Montana)
- Allison Bidlack (Alaska Coastal Rainforest Center)
- Sanjay Pyare (University of Alaska Southeast)
- Dave Tallmon (University of Alaska Southeast)

In addition, the U.S. Forest Service, State of Alaska Division of Forestry, Native Corporations, and land trusts are potential partners on studies of ecological and evolutionary dynamics. Ongoing efforts to assist with research on ecological and evolutionary dynamics include endemic surveys, adaptive management experiments, and studies of habitat demography.

Vulnerability work would be aided by First Nations, citizen science, the USGS EROS Data Center, University of Alaska Fairbanks, and remote sensing labs or entities with range analysis capability. Island Tribes and First Nations are critical partners because traditional ecological knowledge can help, and because these are life and cultural support issues for the Island Tribes and First Nations.

Evaluate the strengths, limitations, and opportunities for the current network of refugia, corridors, and reserves to be resilient to climate change effects

Project participants identified refugia, corridors (especially for dispersal, migration, and biodiversity conservation),[106] and reserves as three management strategies to evaluate and reformulate to incorporate current and potential future effects of climate change (Interior Mountain Ecosystems, Arcata workshop). These activities are urgent to undertake because existing land use pressures may make future action more expensive than immediate action; acquiring land is also a lengthy and difficult process (Interior Mountain Ecosystems, Arcata workshop). Changes to existing reserve systems have already been suggested and offer a starting point for incorporating climate change into future assessments. For example, studies conducted in southeast Alaska‟s Tongass National Forest suggest reformulation of the existing old-growth reserve network would increase the probability of sustaining metapopulations of flying squirrel, an indicator species for old-growth coniferous forest condition in the region (Smith 2005, Smith & Person 2007, Smith et al. 2011). Evaluation and reformulation of these strategies would inform decisions about where to strategically preserve and protect key habitats and species (Interior Mountain Ecosystems, Arcata workshop). As one participant noted:

> *… the idea of reserve systems to maintain a species we‘re concerned about has been a traditional one that I‘m not sure will stand the test of time given climate change… (Interior Mountain Ecosystems)*

The evaluation would address key questions asked by project participants about the resilience of the existing network of refugia, dispersal, migration and biodiversity conservation corridors, and reserves to climate change effects:

- Is the reserve network robust to climate change and where are the gaps? Where are the relatively stable climatic areas and what are their characteristics? (Arcata workshop).
- *…How do we maintain those [reserve] habitats [for a species we‘re concerned about] knowing that these changes will be coming? Little circles on a map may not be the best way to do that (Interior Mountain Ecosystems).*
- Corridors are often species-specific. Which species are moving from where to where, and how will they get there? (Arcata workshop).
- *How can we work with partners to see where there are priorities… where do they merge and where can we bring the most resources together to get the biggest bang for our buck on this landscape? (Interior Mountain Ecosystems).*

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[106] As noted by Hess and Fischer (2001), the term "corridor" defies simple definition, and the roles corridors play derive from the six ecological functions of habitat, conduit, filter, barrier, source, and sink. In this assessment, project participants referred to corridors chiefly in two ways: (1) **habitat corridors,** defined as "components of the landscape that facilitate the movement of organisms and processes between areas of intact habitat" (Meiklejohn et al. 2009, p. 1-2). Examples include *migration corridors* used for annual migratory movements between source areas, *dispersal corridors* for one-way movements of individuals or populations from one resource area to another, and *commuting corridors* that refer to daily movements within a species‟ home range to support breeding, resting, foraging, and other activities (Meiklejohn et al. 2009); (2) **biodiversity conservation corridors**, defined as "a biologically and strategically defined sub-regional space, selected as a unit for large-scale conservation planning and implementation purposes" (Sanderson et al. 2003, p. 10-11).

The overall goal of the evaluation would be to identify desired characteristics and locations for refugia, dispersal and biodiversity conservation corridors, and reserves, which would enable protection or implementation of other management approaches to safeguard the network from climate change effects and related stressors (Arcata workshop). Participants suggested several specific analyses, modeling efforts, or other assessments to meet this goal:

- Understand the past, current, and future climate space across the NPLCC region to determine how climate diversity is distributed (Arcata workshop). This would inform decisions about where to acquire additional land for habitat refugia and efforts to plan restoration and land management activities on a local scale (Arcata workshop). Microclimatic data within the watershed are requested immediately to provide a baseline and enable local conservation action (Arcata workshop).
- Identify and assess the robustness of current Protected Areas for addressing climate change impacts and transitions (WA/OR/n. CA Coast Ranges and Drainages Freshwater, Arcata workshop). For example, conduct a reserve and gap analysis using climate change projections to inform reserve design and conservation financing (WA/OR/n. CA Coast Ranges and Drainages Freshwater, Arcata workshop).
- Use land use data, intactness maps, and integrate climate projections into corridor mapping to identify corridors key species are likely to use or could use if they had access to them (WA/OR/n. CA Coast Ranges and Drainages Freshwater, Arcata workshop).
- Generate predictive models of where key relevant species, ecosystems, and potentially resilient habitats would occur under various climate scenarios to identify important species and habitat refugia and determine how to link and preserve them (Arcata workshop). The models would allow managers to work locally to protect and build resilience in key areas and would support continued protection over time by informing potential land acquisitions (Arcata workshop).
- Develop tools to identify the ―*…location of climatic refugia and connectivity to facilitate climate-forced wildlife migrations…" (Survey Respondent 71)* and *…focus restoration and protection in the areas that have the most potential… (Puget Sound and Georgia Basin Marine).*

The spatial scale for the evaluation and specific analyses varies across the NPLCC region, from landscape-wide to microclimate refugia, but is focused on the existing network of refugia, corridors, and reserves, the location of potential future protected and connected areas, and on the location of key species and habitats.

Across the landscape, north-facing slopes are likely to be important microclimate refugia (Arcata workshop). There is opportunity for coordinated management of old-growth reserves, which include old-growth reserve networks, protected area reserve networks, and managed lands, along the southeast Alaska coastline because there is a physical linkage among the forests (Juneau workshop). In Washington and British Columbia, there is a focus on identifying viable connections between secure habitats from the Olympic to Cascade Mountains and from British Columbia to Washington:

> *… Is there a viable connection between the Olympics and Cascades systems for any species? Can that really be functional? From the Coast to the Cascades looking through BC – that's a real source area [for key species] up in BC – and what are our*

opportunities, challenges, and chokepoints to keep those two systems connected? (Interior Mountain Ecosystems).

Some project participants suggested aligning efforts to connect or improve resilience to climate change effects in key habitats with other conservation and restoration priorities such as addressing altered hydrologic regimes:

> *…Maybe a hydrology priority merging with where I need to make a connectivity investment merging with where an agency really needs to be looking at an issue… (Interior Mountain Ecosystems).*

> *One real specific [effect of climate change on priorities] that we talked about, especially in the NPLCC landscape in Washington is using hydrology…and trying to find areas where we know reducing road densities is critical for a wildlife species overall – be that connectivity or increasing overall core habitat – and trying to align that with watersheds that we know we're getting increasing runoff or increasing hydrologic impacts and basically trying to find as much synergy as we can… (Interior Mountain Ecosystems).*

In California, existing efforts to create a well-connected sustainable system of terrestrial and marine conservation areas are being refined to incorporate species response to climate change effects (AFWA, 2012, p. 6). Participants noted the temporal scale will depend on the rate of change and suggested an initial focus on the decadal scale beginning with the mid-20th century (Arcata workshop).

Several partners and ongoing efforts are suggested:

- The State of California Wildlife Conservation Board has Conceptual Area Protection Plans (CAPPs) and Save the Redwoods League is creating a CAPP with California Department of Fish and Game.
- California Department of Fish and Game is using the Areas of Conservation Emphasis (ACE-II) mapping and modeling tool and establishment of marine reserves "to identify a network of sustainable, well connected conservation areas within California"s borders" (AFWA, 2012, p. 6). ACE-II integrates layers of information on "biodiversity, endemism, stressors and threats (including sea level rise predictions), protected status of lands, and connectivity and corridor information that can be overlaid to contribute to setting terrestrial conservation priorities statewide" (AFWA, 2012, p. 6).
- GreenInfo Network is a GIS repository and analysis for NGOs in California.
- Wendy Peterman at Conservation Biology Institute developed Data Basin, available at databasin.org. Data Basin is a good data repository.
- Geos Institute has many large data sets and regional models including a downscaled regional model of species distribution for thirteen focal species as well as rainforest assemblages and key ecosystem services (e.g., carbon).
- The Nature Conservancy has prioritization of watersheds for salmon called SalmonScape.
- The Wild Salmon Center has salmon strongholds.
- The Alaska Coastal Rainforest Center is a hub for coastal rainforest data and analysis, particularly in the north, and is identifying linkages of habitat under various climate change scenarios.

- To cover the spatial extent of the NPLCC region, project participants suggested using land ownership maps, intactness maps,[107] The Nature Conservancy footprint map, land use and land cover maps (including connecting state and international lands), and a land facets analysis. State and Canadian databases may also be a source of information (Arcata workshop).
- The U.S. Forest Service, National Park Service, and others are doing species vulnerability assessments.
- Museum collections have historic species reconstructions.
- First Nations and other indigenous communities can provide historical and cultural perspectives on species habitats and linkages.

[107] For example, to inform a region-wide forest intactness layer, species distribution models, General Circulation Models (GCMs), land cover types, and associated climate projections would be used (Arcata workshop).

3. Study the interaction of fire with other disturbance regimes given current and potential future climate change effects

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	✓
In-person Workshops	
Portland Workshop	
Juneau Workshop	✓
Arcata Workshop	✓

Fire is a source of natural ecosystem disturbance throughout most of the NPLCC region, including some parts of Alaska, but participants cited fire less frequently across venues and less repeatedly within venues as a major concern in the ecosystems west of the mountain spine (i.e., those within the NPLCC region) than those east of the mountain spine (e.g., west of Cascade Mountains *versus* east of Cascade Mountains, which is outside the NPLCC region). However, participants acknowledged that projections for warmer climates and possibly drier climates, particularly in the summer, raise concerns about increased disturbance from fire.[108] As a result, the major recommendation from participants throughout the region is to acquire an integrated understanding of how fire will interact with other disturbance regimes given current and potential future climate change effects. The emphasis is on understanding future disturbance regimes in order to determine how to respond to stressors and conditions that may be similar or different from the status quo. Project participants from the southern portions of the

[108] By 2100, annual precipitation is projected to increase in the NPLCC region, with the exception of northwest California, where it is projected to decrease (Karl, Melillo and Peterson 2009, Alaska Center for Climate Assessment and Policy 2009, Pike et al. 2010, Climate Impacts Group 2010, California Natural Resources Agency 2009). In Alaska, despite projected increases in precipitation, drier conditions and reduced soil moisture are expected due to increases in evapotranspiration as a result of projected increases in air temperature by 2100 (Karl, Melillo and Peterson 2009). Summer precipitation is projected to decrease and winter precipitation is projected to increase in western British Columbia and the Pacific Northwest (BC Ministry of Environment 2006, Mote and Salathé 2010). Fall and spring precipitation is also projected to increase in western British Columbia (Pike et al. 2010). In southcentral and southeast Alaska, precipitation during the growing season (time period between last spring freeze and first fall frost) is projected to increase (Alaska Center for Climate Assessment and Policy 2009). Seasonal projections for northwest California are needed. For information on baseline conditions, models used, and scenarios used to derive these projections, please see Tillmann and Siemann (2011a, 2011b). DellaSala et al. (*in review*) also projected changes in annual precipitation by the 2080s (1950-2000 baseline) based on three GCMs (CSIRO, CCCMA, HadCM3) under the A1B emissions scenario. Their findings are consistent with those described above with two exceptions: the CSIRO and CCCMA models project increased precipitation in northwest California (as opposed to decreased precipitation), and the HadCM3 model projects decreased precipitation in southwest British Columbia, western Washington, and western Oregon (as opposed to increase precipitation).

NPLCC region and the Kenai Peninsula in southcentral Alaska requested this information more frequently across venues or repeatedly within venues than their counterparts in British Columbia and southeast Alaska. In addition, participants working in California – the most fire-prone area of the NPLCC – provided specific suggestions for addressing fire as a source of disturbance in forested ecosystems. Activities for fuels and fire fall into these two categories:

- Investigate interactions between fire and other disturbance regimes
- Address fuels, fire, and forest management in northwest California‟s historically fire-suppressed ecosystems

Investigate interactions between fire and other disturbance regimes

Project participants from throughout the NPLCC region independently requested efforts to understand and address interactions between fire and other disturbance regimes:

- Understand how fire interacts with other disturbance regimes to identify key thresholds or indicators to measure. Also, understand how individual tree or vegetation/species respond to fire and other climate stressors (Arcata workshop).
- Acquire information on fuels, vegetation changes, insects, disease, sudden oak death, thresholds, indicators, and mismatches (Arcata workshop).
- Understand the impacts of disturbance regimes attributed to climate change, on ecosystems (fire, windstorms, insects and pathogens, direct climate on trees, landslides, floods) (Juneau workshop).
- Understand*…what effects those changes might have on fire regimes – there is actually some degree of fire in part of our area [Chugach National Forest, Alaska] – avalanche, and other potential disturbance mechanisms and how humans could actually alter the outcomes of these changes and what we might end up with (Coastal Temperate Rainforest Ecosystem).*

In addition to the general research and information requests described above, research syntheses and development of tools and scenarios were also suggested:

> *Hav[e] data (e.g., Science Synthesis) available for managers to incorporate and use for planning effort, such as information on changing fire season, length, duration, and intensity of disturbances (Arcata workshop).*
>
> *―We could use advanced, ground-truthed modeling tools to integrate fire risk, climate change, and sensitive/vulnerable resources, and a cohesive research/management group to keep it up to date…" (Survey Respondent 65).*
>
> *Perhaps one of the most useful things coming out would actually be generating various scenarios of potential changes, a range of different future states (Coastal Temperate Rainforest Ecosystem).*

Improved understanding of the interaction between fire and other disturbance regimes given current and potential future climate impacts would provide an ecological basis for land management planning, developing adaptation strategies, and preplanning strategic adaptive treatments that reduce high fuel load and increase forest resilience to climate change. For example, scenario development could inform vegetation management decisions:

> *Quantifying expected ranges of variability is something that would be desirable and helpful for us to put into context, the changes that we might be expecting to see with climate change and could help us predict outcomes of various vegetation management we might try to do to respond to change (Coastal Temperate Rainforest Ecosystem).*

The research, synthesis efforts, tools and scenarios may also lead to project-specific prescriptions for forest treatments and would inform decisions about the old-growth reserve network in the Tongass National Forest. Finally, combining traditional ecological knowledge with science or science syntheses would inform community cultural planning.

Participants also identified a number of barriers to responding to these requests including the provisions of current management plans, Clean Air and Clean Water Acts, the Endangered Species Act, the longevity and effectiveness of treatments implemented, and the "risks" associated with alternatives for treatment types (Arcata workshop). To address these barriers, increased efficiency and collaboration are suggested:

> *―As our challenges as land managers increase while funding declines, we will need to become much more efficient at identifying priorities for ecological restoration and carrying out these projects in collaboration with multiple partners" (Survey Respondent 65).*

The spatial scope for this work is NPLCC-wide, using a nested approach compatible with the scale of events and ranging from plot and stand level measurements correlated with landscape distribution of different vegetation types to patches to large areas (thousands of acres). The temporal range for this work is -200 to +200 years, with an initial focus on short-term (1-5 year) effects to identify thresholds that allow for scaling up (10 to 100+ years). All work should incorporate the longer fire seasons expected.

The timeline for the work is over the next five years to get the basis for forest planning and emphasize a planning-oriented approach (versus a crisis-oriented approach). However, current applications for local to landscape-level fuels and fire planning typically exclude tribal and community "values at risk" in favor of ecological processes or vulnerable species (e.g., refugia). It is urgent to incorporate tribal and community values in these processes, as well as the interactions between species, ecological processes, and disturbance.

In the northern latitudes of the NPLCC region, the U.S. Forest Service State and Private Forestry Forest Health Protection, National Park Service, Tongass National Forest, Chugach National Forest, downscalers (PCIC, CIG, SNAP), and rural and native communities were identified as potential partners.

In the southern latitudes of the NPLCC region, particularly southern Oregon and northwestern California, regional centers for federal and state agencies such as the U.S. Forest Service‟s Pacific Northwest and Pacific Southwest Research Stations and U.S. Department of Interior Northwest and Southwest Climate Science Centers are potential partners because they work on Forest Plan revisions. Fire management programs within the U.S. Forest Service and National Park Service may have relevant information or resources to share. At the local level, Fire Safe Councils, Tribes, and academia (research at local to regional scale) are potential partners. In addition, county and city government and civic groups such as the California Native Plant Society may be able to assist.

Address fuels, fire, and forest management in northwest California's historically fire-suppressed ecosystems

While fire is a natural part of most of the NPLCC"s terrestrial ecosystems, northwest California is currently the most fire-prone region within the NPLCC geography:

> *…when looking at the large geographic area that the NPLCC covers, the California portion of it may be a bit different than the rest with regard to the rainfall patterns, the dryness of the summers, and also the related fire regime that we have to deal with here…We have dry summers even in the northwest coastal areas…We have fire as a stressor – a normal stressor – that I know Alaska doesn't have and in western coastal Oregon and Washington is not as big a big factor (Interior Mountain Ecosystems).*

Fire suppression was an active management strategy for many years and in some cases is still in practice:

> *We have suppressed fire for many years and to some degree we still have to do that because there are people on the landscape (Interior Mountain Ecosystems).*

Furthermore, there has been an overall increase in fire severity and acres burned (Interior Mountain Ecosystems). The ability to treat fuels is *lagging behind the rate at which they're burning up by about a factor of 2* and managers are *not able to strategically put the fuels treatments in places they would be specific to protect habitats or to adapt to climate change – they're really to protect homes and towns (Interior Mountain Ecosystems).* The challenges of managing these historically fire-suppressed systems are likely to be exacerbated by climate change:

> *I think people recognize the discrepancy of what likely would have been on the landscape and what the systems would be adapted to versus what we have now – that gap will likely increase with climate change effects increase over time. So we're trying to do those treatments, but it's tough, and with budgets going down I'm not sure. It will be a challenge (Interior Mountain Ecosystems).*

With these challenges in mind, web-based focus group and Arcata workshop participants provided specific information and suggestions for managing fuels and fire in northwest California forests:

- Acquire stand-level fuels data to identify what and where is vulnerable.
- Downscale climate change scenarios to the management unit or stand level. With existing models, high uncertainty in the downscaled data is likely.
- Increase the pace and scale of fuel reduction across the landscape.
- Produce information on missing habitats and tree response to stressors.
- *We need to identify or quantify what the effects of various fuels and forest management treatments would be both on the behavior of the watershed hydrologically – the streamflow regimen in particular, the effect on transpiration – and what would be the effects of a change in*

the fire regime on the hydrology and sediment regimen, and how would that affect the water delivery infrastructure that we have in the national forests. (Interior Mountain Ecosystems)

Information on stand-level fuels data, missing habitats, and tree response to stressors would inform the development of vulnerability assessments, adaptive fire prescriptions, and mechanical approaches to addressing vulnerable species and habitats. Efforts to identify vulnerable species and habitats may need to begin immediately depending on the habitat value (e.g., refugia, endemics, vulnerable communities, corridors).

Climate change will affect forest management in California, including direct impacts on water resources and a risk of impacts on water resource infrastructure. Identifying, quantifying, and understanding the interaction of climate-related impacts to fuels and fire on hydrology and sediment regimes would inform forest management decisions related to water resources and associated infrastructure. It would also assist efforts to balance short- and long-term habitat needs:

We have to balance maintaining those late-seral forest systems but also recognize that if we let them go, they will burn eventually and we'll lose that habitat. That links back to the short-term vs. making sure there is habitat for the long-term (Interior Mountain Ecosystems).

Finally, management strategies that emphasize a transition to prescribed fires will enable management outcomes to extend from protecting communities to maintaining forest health under changing environmental conditions:

Most of the fuel treatments taking place on the national forests are for community protection. We're not able to strategically put the fuels treatments in places they would be specific to protect habitats or to adapt to climate change – they're really to protect homes and towns. We would like to expand that and eventually the goal would be to maintain forest health with prescribed fire rather than having to do the expensive mechanical treatments which are necessary now because the forests are overgrown now to the point where we can't safely use prescribed fire in too many places (Interior Mountain Ecosystems).

Steve Norman, Research Ecologist with U.S. Forest Service Southern Research Station, may have a data set for the redwoods. Diana Craig (U.S. Forest Service Region 5 Wildlife Ecologist) and Barry Hill (U.S. Forest Service Region 5 Hydrologist) are potential resources for information on balancing short-term and long-term needs and hydrologic implications, respectively (to contact, see U.S. Forest Service employee directory). Dave Roemer, Chief of Resource Management and Science, is a contact for the National Park Service out of Redwood National Park.

4. Conduct more and better coordinated assessments of climate change effects on fog patterns and forest hydrology northwest California

A key issue for those currently working in northwest California is to understand potential changes to fog and fog-associated hydrology regimes and the effects they may have on coastal redwood forest health and resilience (Coastal Temperate Rainforest Ecosystem, Arcata Workshop). Those currently working in coastal temperate rainforests farther north, particularly Oregon and Washington, are also interested in understanding these changes, as warmer climates may make more northern latitudes suitable for coastal redwood forest ecosystems (Coastal Temperate Rainforest Ecosystem, Arcata Workshop). While there is an active research community in northwest California investigating these questions, much of the research is in its early stages and is just beginning to be coordinated and communicated with the broader stakeholder community:

> *I have limited resources available for how things would affect coastal redwood forests down here in northern California, but I do feel it's an area where given how fragile those ecosystems are and marginal they have become, that would require some real specific study. There is some data and research being done, but it is pretty limited (Coastal Temperate Rainforest Ecosystem).*

Web-based focus group and workshop participants identified two major categories of potential focus for the NPLCC:

- Conduct research and vulnerability assessment on the effects of changing hydrology on forest health and resilience
- Leverage and build upon existing efforts to coordinate fog research

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	✓
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	
Juneau Workshop	
Arcata Workshop	✓

Conduct research and vulnerability assessment on the effects of changing hydrology on forest health and resilience

To advance the ability to conserve and manage coastal redwood forest ecosystems in the NPLCC region, Arcata workshop participants suggested the following avenues of research:

- Research on fog, wind, and evaporation and the effect of forest change on slope stability and runoff.
- Study how decreased snowpack under current and future climates influences ecosystem water balance.
- Track routing of sediment due to hydrologic change.
- Conduct vulnerability assessments to determine which species are susceptible to change due to changes in fog and snow.
- Extract oral history from anthropological libraries such as Bancroft Library at UC Berkeley from the early 1900s.

Participants indicated these research avenues should be pursued as soon as possible because this information is a prerequisite for determining target areas for treatment and treatment design. A better understanding of climate change effects on fog, hydrology, and sediment regimes would inform and enable decisions about conservation and restoration priorities such as land acquisition to protect key locations. It would also provide information on how hydropower and related energy sources may be impacted in the region. Research on the routing of sediment due to hydrologic change would also inform current and potential future regulatory requirements such as Total Maximum Daily Load (TMDL) studies. Furthermore, soil moisture and temperature affect the abundance and distribution of pest populations in the landscape. An improved understanding of likely changes to ecosystem water balance and resulting changes in soil moisture, soil temperature, groundwater recharge, and other factors would therefore inform pest management. The study of oral history would inform decisions by providing a new historical perspective and understanding of environmental change across the landscape and identifying potentially novel management strategies.

The spatial scale of research should utilize a nested approach and extend throughout the range of the redwoods, from watershed headwaters to coastal dunes. The temporal scale is the last 2000 years, from the age of the oldest redwood to the period of the Industrial Age and on to the next fifty years. Data on species selected for vulnerability assessments should be collected under historic and current climates, then projected using future climate models and scenarios.

For assistance with research on fog, wind, and evaporation and the effect of forest change on slope stability and runoff, NASA‟s Ames Research Center in Sunnyvale, California is studying extreme life. The U.S. National Weather Service and Save the Redwoods League are also potential partners. The effects of reduced snowpack on ecosystem water balance are or were under investigation by:

- Jenny Curtis and Lorrie Flint with the U.S. Geological Survey (see employee directory)
- Connie Millar with the U.S. Forest Service Pacific Southwest Research Station
- Anne Nolin at Oregon State University
- Christina Tague with the University of California, Santa Barbara.

California Regional Water Boards, the U.S. EPA, U.S. Geological Survey, and California Geological Survey have expertise related to the routing of sediment due to hydrologic change. Finally, forest restoration is ongoing in California State Parks.

Leverage and build upon existing efforts to coordinate fog research

Project participants stated improving coordination efforts on fog research should be addressed as soon as possible. More coordinated efforts on fog research would inform development of a fog classification system, as well as species conservation, acquisition or allocation of public lands, and understanding the status of ecosystems under historic and current climates. The lack of observational data on historic conditions, for example, can be addressed by supporting isotopic analysis of tree rings and engaging with an international fog working group.

Efforts to understand the role of fog in ecosystems are a burgeoning area of study internationally, nationally, and regionally. Working groups have formed at the international level and regional efforts by Humboldt State University and Save the Redwoods League are advancing and coordinating research in northwestern California. Arcata workshop participants highlighted the value of these early efforts and suggested the NPLCC could further advance coordination of fog research, both within the NPLCC and across other boundaries. New and existing data should be ecoregion-based and available in nested temporal and spatial scales.

A number of potential partners and ongoing efforts are available in the region including groups studying atmospheric moisture and fog such as Save the Redwoods League, the U.S. Forest Service at Caspar Creek, Humboldt State University, Oregon State University"s work at the H.J. Andrews Experimental Forest, and Cliff Mass at the University of Washington. The U.S. Geological Survey Western Geographic Research Center also hosted Pacific coastal fog workshops and may have results to share.

5. Support to advance efforts to address climate change in the Willamette Valley, Oregon

Much of the discussion in the Lowlands, Prairies, and Other Non-forested Ecosystems web-based focus group centered on existing and planned projects in Oregon‟s Willamette Valley, and support the NPLCC could provide to facilitate further work. This section begins with background information on current climate change-related work in the Willamette Valley provided by project participants, then reviews the three activities identified by project participants as those the NPLCC could help pursue:

- Background information on current climate change-related work in the Willamette Valley
- Develop guidance and scenarios to compare management options and inform decisions
- Enhance cross-boundary collaboration within and across institutions and areas of expertise
- Facilitate science communication and outreach with the public

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	
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California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	✓
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	
Juneau Workshop	
Arcata Workshop	✓

Background information on current climate change-related work in the Willamette Valley

Project participants working in the Willamette Valley, particularly those working with the U.S. Fish and Wildlife Service (FWS), identified three major focal areas for their work:

- Develop and implement refuge planning documents known as Comprehensive Conservation Plans every ten years. These are …*based on the best available climate science and information in a variety of contexts from the big picture down to the specific management units on our wildlife refuges and try to address the implications from climate change to habitats and species (Lowlands, Prairies, and Other Non-forested Systems).* The Willamette Valley NWR Complex is currently revising their CCP (draft available here – 16.32 MB PDF; status updates available here).
- Engage in public education and outreach that aims to develop …*good information to share with the public to try to gain their understanding and appreciation for the complexities of climate science and climate change… (Lowlands, Prairies, and Other Non-forested Systems).*

- Partner with other agencies, communities, and stakeholders in land protection planning efforts such as new or expanded refuge areas and …*using climate science information to help ascertain our priorities and make sure we focus our efforts and limited funding in the right areas… (Lowlands, Prairies, and Other Non-forested Systems).*

As an example of a land protection planning project that is incorporating climate change science, project participants identified the Willamette Valley Conservation Study (WVCS), a joint effort between FWS, partners, and stakeholders. As stated on their website, WVCS is a "collaborative, multi-year study of land and water conservation opportunities within Oregon's Willamette Valley" initiated in Fall 2011. Project participants are currently *…working with partners and other agencies, as well with the Service to look at conservation tools that could range from private lands, partner initiatives to conservation easements and possible new or expanded wildlife refuge areas (Lowlands, Prairies, and Other Non-forested Systems).*

The goal of exploring the conservation tools available for the landscape is to *…help identify the future conservation state… (Lowlands, Prairies, and Other Non-forested Systems).* In order to meet this goal, FWS and their partners are using a variety of data, information, and models to inform their decision making process. These include existing data and information from the State of Oregon, FWS, The Nature Conservancy, and others on current priorities for species and habitat types that need protection as well as incorporating the best available information on climate, species and habitat vulnerability to assess if and what actions may need to be taken:

> *…we have general information from the state, our own data sources, TNC, and others on a range of priorities for various species and habitat types…[that] need protection, and then of course we want to incorporate the best information on climate and species and habitat vulnerability in those areas that might need to be addressed in certain ways, whether they need protection or…perhaps the vulnerability is so high and risky that maybe other actions and immediate needs – translocation or other activities [are needed]. The flip side of that is those species and habitats that are expected to be more resilient – do we have enough of those areas protected or do we need to add to the conservation state? (Lowlands, Prairies, and Other Non-forested Systems).*

FWS and partners are also developing new models to articulate when and where management options may arise in the future. These models address issues with sporadic habitat and vegetation land cover at the site-specific scale and include vegetation distribution, vertebrate distribution, and land asset models that incorporate factors affecting species distribution such as slope elevation (Lowlands, Prairies, and Other Non-forested Systems). Once the models are developed, FWS and partners plan to work with the University of Washington Climate Impacts Group to synthesize model results and explore future options for land protection:

> *…When all of that modeling effort is completed, and that's going to be sometime late summer, there will be a workshop where the UW folks will come down and work with us on synthesizing the results of those models, to see what the best way to overlay them to identify things like temporal corridors where the bioclimatic conditions will remain suitable over term for some of the species and systems we're concerned with. Some of the future distribution models might point to corridors or new areas we might want to protect as additions to the NWR system… (Lowlands, Prairies, and Other Non-forested Systems).*

The Willamette Valley is the first area undergoing this assessment. The Lower Columbia River and Puget Sound have been identified as future project locations (Lowlands, Prairies, and Other Non-forested Systems).

In a related study of climate change impacts and adaptation strategies for the prairies and oak savannas in the Willamette Valley-Puget Trough-Georgia Basin ecoregion, Bachelet and colleagues (2011) suggested six broad climate change adaptation strategies for the ecoregion:

- Use the full geographic and climatic range of prairies and oak savannas to enable species to shift throughout the region.
- Utilize existing habitat heterogeneity, which may mean facilitating new community types, species shifts into new microhabitat types, or identifying refugia that will persist over time.
- Manage existing sites adaptively and expand prairie conservation areas strategically, for example by adding species or functional groups to facilitate changes in community composition or altering the location, amount, and timing of prescribed fire.
- Establish new prairies and oak savannas on lands where more susceptible communities have been displaced by climate change. To do so, employ restoration techniques that will establish native species efficiently under new conditions and establish a regulatory framework and public awareness to aid the transition to these land use changes.
- Leverage the ecosystem services provided by prairie and oak savanna, such as carbon sequestration and in some cases, buffering hydrologic flows, to enhance conservation and restoration opportunities.
- Monitor climate conditions and threshold responses by biological communities in prairie and oak savanna, including adjacent timberland and agricultural land, especially where more susceptible to abandonment or climate change-induced dieback from reduced water availability in the growing season.

Develop guidance and scenarios to compare management options and inform decisions

Project participants working in the Willamette Valley requested guidance to compare and select management options associated with land acquisition and protection:

> *…I am not hearing a lot that helps me understand how I should manage a piece of land or even how I should choose a piece of land that I should include in the Refuge system. It's those pragmatic questions that I struggle with… (Lowlands, Prairies, and Other Non-forested Systems).*

Assistance to understand the implications of conflicting scientific results was also requested by project participants. For example, some models show Oregon white oak moving north, out of the valley and spreading throughout the NPLCC (Lowlands, Prairies, and Other Non-forested Systems, Arcata workshop), while others …*say that the valley won't be hit too hard and will stay pretty much in place… (Lowlands, Prairies, and Other Non-forested Systems).* In both scenarios, localized losses would not lead to total losses (Arcata workshop), but in order to make management decisions, information on what is likely to occur in the Willamette Valley is requested:

> *…Trying to shift through all of those conflicting results [about Oregon white oak], a lot of people are going have to synthesize that and come up with plausible scenarios. We're developing a plan that will be implemented over many years so there will be the opportunity to revise it as we move forward (Lowlands, Prairies, and Other Non-forested Systems).*

A second example of assistance to understand the implications of conflicting information in the Willamette Valley is addressing contradictory results from vegetation land cover models. This example highlights that models may agree at a coarse scale, but disagree on a fine scale, which introduces uncertainty into decision making processes:

> *…in the PNW, general information on habitat, ecosystems, communities – that level of information at the general scale is probably fairly adequate but as we zero in on more site-specific areas within the Willamette Valley Study Area for example, we find our habitat and vegetation land cover information is sporadic, it's incomplete, and some of the vegetation land cover models don't agree with each other. Ideally we would have those to a resolution from the coarse-scale down to the fine-scale of detail – very well-polished and agreed to by the majority of our partners and participants (Lowlands, Prairies, and Other Non-forested Systems).*

To improve resolution at finer scales, project participants indicated that while GIS land cover and vegetation would be useful, ground-truthing ensures accuracy of the GIS data gathered from imaging technology:

> *…we would use in GIS land cover and vegetation, basically vegetation community mapping. To do that correctly you have imagery, ground-truthing, more than just gathering great GIS data from imaging. It needs the ground-truthing side of the equation as well (Lowlands, Prairies, and Other Non-forested Systems).*

Enhance cross-boundary collaboration within and across institutions and areas of expertise

Project participants in the Pacific Northwest, specifically those working in the Pacific Region of the U.S. Fish and Wildlife Service, suggested cross-boundary collaboration as a potential role for LCCs:

> *It seems to me that is the value of LCCs – you have a lot of people from different agencies talking together, I think that would be a great way to help us inform our other partners (Lowlands, Prairies, and Other Non-forested Systems)*

Cross-boundary collaboration includes collaboration across LCCs, as well as across states and ecoregions within a particular LCC:

> *You certainly don't want to look at anything in a vacuum. In the sense of the overall LCC, the NPLCC, Great Northern LCC, and Great Basin LCC are all in our Pacific Northwest region, so at that scale we have to make sure we have integration across those boundaries. Within the LCCs, a state-by-state or other ecological systems basis, we need to be able to identify problems across those areas, what's more vulnerable, what's more of an issue in one system or more at risk in another, certainly that may cause us to emphasize that more than in other areas. In general, integration across all those scales is going to be important to me (Lowlands, Prairies, and Other Non-forested Systems). Hyperlinks added.*

Approximately half of those participating in the Lowlands, Prairies, and Other Non-forested Systems web-based focus group supported the role of the NPLCC as a convener of diverse stakeholder groups. They also supported development of a "Climate Clearinghouse," which is discussed in greater detail in Chapter III.2 (p. 28). As stated by one participant, facilitating collaboration across different areas of expertise addresses the inertia and "silo" effects that make it difficult to collaborate effectively:

> *I think the value of the LCC is that it provides a forum for these groups working on different aspects of the region…to provide their information in a way that we can go to a source and meetings, perhaps a data information portal…There is the aspect of individual researchers getting stuck in their area of interest. Unless we're actively looking to understand what else is being done that may be relevant to what we're doing, we're not going to do it, so I think that just by virtue of organizing what different people are doing that will help us to see how we can better work together (Lowlands, Prairies, and Other Non-forested Systems).*

Facilitate science communication and outreach with the public

Project participants expressed support for improved communication and outreach with the public, stating *…one of the needs we have is good science education and outreach materials that we can provide to people who come to the [Willamette] NWR and to also incorporate into our materials and plans (Lowlands, Prairies, and Other Non-forested Systems).* They emphasized the need for "good, consistent language" and provided specific suggestions for the types of communications materials that would be helpful for public outreach:

> *…It could be a brochure for visiting public in general. We have seen a little of that but it is really general information. In the sense of the LCC, whether it's divided by ecoregions or something else, they could probably develop some of these materials agencies could use just as general public information and then more specifically, if we're doing a project on a specific refuge or study area, information that would help to relate to the general public. What are the climate change issues of this area and how are the agencies addressing it? The latter may be more our part but we could use your help in producing that information (Lowlands, Prairies, and Other Non-forested Systems).*

VIII. Activity Areas for Rare, Endemic, Vulnerable, and Keystone Species

The most frequently discussed rare, endemic, vulnerable, and keystone species by project participants were Pacific salmon and forage fishes, followed by amphibians and small mammals such as flying squirrels. While project participants stated climate change effects on these species and species groups are important to address in their own right, there was a greater emphasis on the role of these species in determining ecosystem health, resilience to climate change effects, and as culturally and economically significant species. These species perform key functions in the ecosystem such as nutrient transfer and habitat maintenance, and are critical to maintain obligate symbiotic relationships in the ecosystem. Moreover, Pacific salmon are necessary to sustain the Way of Life for many Tribes and Native Alaskans throughout the NPLCC region (see Chapter IV, p. 54 for more information).

The activity areas for rare, endemic, vulnerable, and keystone species are:

1. Assess the vulnerability of Pacific salmon, other anadromous fish, and their habitats to climate change effects
2. Generate research and models for forage fishes
3. Identify focal indicators to track climate change and assess management options (e.g., small endemic mammals, amphibians)
4. Develop maps and models to address climate change effects on other key fish species

Within an activity area, several specific activities requested by project participants are described. The description includes information on how many project participants identified the activity and the climate change-related challenges associated with pursuing the activity. To provide information to the NPLCC about when, where, and under what circumstances support is requested, participant evaluations of the activity across the four evaluation criteria are synthesized:

5. *Decision-relevance* indicates which decisions the activity would help inform or guide.
6. *Timeline or sense of urgency* indicates when the activity is needed and provides a sense of why and how important, or urgent, it is to pursue the activity.
7. *Spatial and temporal scale* identifies the necessary geographic region or spatial coverage for the activity and whether the activity is needed on an annual, seasonal, daily, etc. timescale.
8. *Partners and ongoing efforts* identifies the people, partnerships, and organizations that might already have information about the activity or might be well suited to develop it.

1. Assess the vulnerability of Pacific salmon, other anadromous fish, and their habitats to climate change effects

Project participants from throughout the NPLCC region highlighted Pacific salmon as a key topic of concern throughout the region. Other anadromous fish such as coastal cutthroat trout, eulachon, and lamprey were also identified as vulnerable to climate change effects and important to address, but detailed discussion of the climate change-related challenges, needs, and opportunities for other anadromous fish was set aside to focus instead on Pacific salmon and, to some extent, forage fishes. Specific activities suggested are:

- Study and monitor the effects of climate change on Pacific salmon lifestages
- Assess the vulnerability of Pacific salmon to climate change effects
- Map current and projected Pacific salmon habitat

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	✓
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	✓
Columbia River Basin	✓
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	✓

Study and monitor the effects of climate change on Pacific salmon lifestages

Additional research on the effects of climate change throughout the Pacific salmon lifecycle was discussed most frequently by project participants in the southern extent of the NPLCC. Within the southern extent of the NPLCC, there was a further emphasis on the marine and estuarine phases of the lifecycle. One rationale provided for this focus is the paucity of knowledge about the combined effects of climate change and ocean acidification on primary and secondary ocean productivity (Fabry et al. 2008, Peterson and Schwing 2008, Rykaczewski and Dunne 2010). During the marine phase of their lifecycle, Pacific salmon depend on primary and secondary producers such as pteropods for much of their diet (Bollens et al. 2010, Fabry et al. 2008). A second reason for the suggested research focus on the marine and estuarine phases of the lifecycle is that most research on Pacific salmon investigates the freshwater phases of the lifecycle. For example, in British Columbia:

> *We've spent the last 25-30 years focused on freshwater ecosystem restoration science and application of that to habitats, particularly salmon and steelhead on [the east coast*

of Vancouver Island]…[We] have largely ignored what's happened to our estuaries (Puget Sound and Georgia Basin Freshwater).

Some studies on the estuarine phases of the lifecyle have been completed, but participants requested additional studies to better understand the importance of the estuarine interface for juvenile fishes:

There have been some great seminal studies done in Puget Sound and down in Oregon and northern California, but there's really a paucity of really good information here that addresses how critical the estuarine interface is for juvenile fish, particularly young salmon and Chinook salmon in particular (Puget Sound and Georgia Basin Freshwater).

In Washington and British Columbia, participants suggested that one area for future research is the impact of increasing salinity due to sea-level rise on the riparian habitat used by juvenile salmonids:

[Something that really needs to be addressed is] the issue of sea-level rise and how that might impact some of those sedge communities which are very intolerant of high salinity levels and also some of the riparian vegetation that turns out to be critically important to the early life stage of so many salmon species in estuaries… I think that in the British Columbia context, there's a real lack of vigorous or robust scientific information that deals with that. I would certainly support what [another participant from Washington] has said about that being an area that needs further scientific and public attention (Puget Sound and Georgia Basin Freshwater).

Despite the seminal studies from Oregon, web-based focus group participants from Oregon requested additional information on juvenile salmonid use of the estuary and tidal wetlands (California Current Marine #1). This includes the oligohaline and freshwater tidal zones as well as brackish, fresh, emergent, scrub-shrub, and forested tidal wetlands (California Current Marine #1).

For the freshwater stages of the lifecycle, Portland workshop participants suggested research to match coldwater locations with life-history information on ESA-listed species that utilize the mainstem of the Willamette River in Oregon. This would inform ESA recovery and prioritization of protection and restoration activities. Over the next five years, species-specific research on egg tolerance and adaptive capacity is also suggested. Finally, on the north coast of British Columbia, support for monitoring would help address key challenges:

We work on the Kitwanga River where there is a run of genetically unique sockeye salmon spawning in the lake. Like most of the region there is no money for long term monitoring of the salmon and their habitat such as water temperature which is critical for their survival. Most monitoring is through private projects. It is a struggle to do annual temperature monitoring (Pacific Coast and Nass Ranges Freshwater).

In British Columbia, ESSA Technologies is a potential partner due to their collaborative work with the Pacific Fisheries Resource Conservation Council, Department of Fisheries and Oceans, and other partners on the impacts of climate change on Pacific salmon. Other potential partners include:

- Jeff Duda (U.S. Geological Survey) studies the distribution and abundance of Pacific salmon in Puget Sound (WA).

- Allison Bidlack (Alaska Coastal Rainforest Center) developed habitat models for Chinook salmon in the Copper River watershed (AK).
- David Beauchamp (University of Washington) coordinates research on fisheries resources. Current work includes "an examination of climate change effects on distribution, energetics, growth and survival of pink salmon the Gulf of Alaska; investigating the early marine life history, temporal distribution, trophic interactions, growth and survival of salmon in Puget Sound; food web dynamics, growth, survival, distribution, and contaminant bio-accumulation of resident and anadromous fish in large lakes; development and application of visual foraging models for piscivorous and planktivorous fishes."

Assess the vulnerability of Pacific salmon to climate change effects

Project participants from throughout the NPLCC region suggested assessing the vulnerability of Pacific salmon to climate change effects to determine which stage of the lifecycle is more vulnerable to climate change:

> *…We also need to look at the vulnerability of salmon stocks. What stage of the lifecycle is more at risk both in fresh and marine systems? We don't know much about the ocean and salmon. Would like to see a lot more work going into the marine environment (Pacific Coast and Nass Ranges Freshwater).*

In the southern NPLCC, there was a specific emphasis on the vulnerability of hatchery fish in comparison to wild fish, as well as the vulnerability of hatchery programs. A better understanding of the vulnerability of hatchery and wild fish to climate change would help determine the vulnerability of sport and commercial fisheries to climate change, as well as improve understanding of competition between hatchery and wild fish under changing climatic conditions (Portland workshop). Hatcheries are also an important component of tribal salmon restoration efforts in the Pacific Northwest. The vulnerability of hatcheries to climate change is a particular concern for Tribes:

> *―..One specific research idea that we have not seen addressed is an evaluation of current hatchery programs and how they may be affected by climate change (i.e., are hatcheries sited in areas where water temperatures will be too warm in the future?), because hatcheries currently play such an important role for the tribes in salmon restoration" (Survey Respondent 28).*

In the northern NPLCC, the response of Alaska‟s salmon stocks to climate change is likely to differ from salmon stocks in the Pacific Northwest and California. There is less human intrusion on salmon habitat in Alaska, which reduces vulnerability to climate change (Alaska and British Columbia Coast Freshwater). However, small or isolated runs of salmon may be quite vulnerable, particularly where thermal or physical barriers isolate the population (Alaska and British Columbia Coast Freshwater)*:*

> *Brings up concerns about the possible vulnerability of certain populations even in Alaska such as small runs of salmon or those that are isolated due to location, e.g. above barriers (Alaska and British Columbia Coastal Freshwater)*

As is true elsewhere, participants noted there will be winners and losers with climate change – *there will be some populations who will not survive and others that will thrive with the changes (Alaska and British Columbia Coast Freshwater).* Those working in Alaska suggested several research areas to help determine which salmon stocks are likely to win or lose and develop strategies to address those populations that may be on the losing side:

- Study the response of salmon populations to environmental stressors associated with climate change. This will provide information about which species or stocks may be able to adapt to climate change.
- Identify locations that will provide viable salmon habitat in the future. Good monitoring will be critical to identifying viable salmon habitat, both now and into the future:

  We need to have good monitoring…This is particularly important in terms of restoration because we need to decide where we want to focus funds. Even if it is a productive area today it is possible that it will not be productive in the future. We need to decide if we want to focus on possible future productive areas instead of currently productive areas (Alaska and British Columbia Coast Freshwater).

- Assess the current and future productivity of ecosystems utilized by salmon, including the changes and transitions likely to occur. This will inform assessments of current and future vulnerability to change.

A potential source of information on the vulnerability of Alaska salmon stocks to climate change is the vulnerability assessment currently underway in southcentral Alaska. This assessment includes downscaled climate projections by the Scenarios Network for Alaska and Arctic Planning (SNAP) and university and interagency teams reporting on the following topics: salmon, biome-shifts, cultural resources, snow & ice, and coastal resources.

Finally, in response to a question about existing plans or programs to respond to changes, one web-based focus group participants suggested *life history diversity as potential adaptive management tool. Fisheries management opens and closes to allow for diversity. It is possible that this method might be useful in other areas as well (Alaska and British Columbia Coast Freshwater).* The participant also noted there is no attempt to coordinate adaptive management tools and suggested this may be an area in which the NPLCC could connect people and projects (Alaska and British Columbia Coast Freshwater).

Map current and projected Pacific salmon habitat

Project participants stated maps of current and projected salmon habitat would improve understanding of habitat viability and utilization as well as inform decisions about which habitat to protect. One suggestion is to *…map[ping] groundwater areas and determin[e] the contribution of groundwater in late summer when river temperatures are high and flows are low* because *ground water and the sources of rivers are the key sources salmon spawning (Pacific Coast and Nass Ranges Freshwater).*

To inform difficult decisions about deciding which habitat to invest funds in for protection, one web-based focus group participant suggested a map-based decision-support tool used by the Climate Impacts Group. The tool works with streamflow gauge data to perform shifts of statistical flows of rivers and map the location of potentially viable salmon habitat in the future (Puget Sound and Georgia Basin Marine). For example, the tool has been used to identify if and how current salmon habitat in the Boise River may change with climate change. It shows areas that will no longer be viable for salmon habitat, areas that will remain relatively unaffected by climate change, and areas that may be viable habitat if they are protected (Puget Sound and Georgia Basin Marine).

Arcata workshop participants also suggested The Nature Conservancy‟s SalmonScape and the Wild Salmon Center‟s salmon strongholds as helpful visualization tools for salmon habitat. Both systems provide information that suggest or inform prioritization of watersheds for salmon.

2. Generate research and models for forage fishes

Forage fishes were cited most frequently by project participants working in southeast Alaska, the Strait of Jean de Fuca, Puget Sound, Georgia Basin, and California Current regions. Participants from these regions highlighted the critical role played by forage fishes in the nearshore environment, emphasizing that the capacity to manage forage fishes in a changing climate will be critical for maintaining the overall health and resilience of the nearshore and offshore marine ecosystems as well as the freshwater habitats utilized by anadromous fish (Puget Sound and Georgia Basin Marine, California Current Marine).[109]

However, during workshops, forage fishes were combined with other topics (e.g., salmon and other coldwater fish in Portland, marine and aquatic organisms in Juneau) and further elucidation of climate-related research and decision-support activities was largely overshadowed by discussion of large-scale impacts (e.g., sea level rise) or other key species, especially salmon. As a result, the information in this section is somewhat general and limited. Nonetheless, the clear importance of forage fishes in the ecosystem and to experts and stakeholders working in much of the region indicate forage fishes should be covered explicitly in this report. The activity identified for forage fishes is:

- Research and model the vulnerability and response of forage fish to climate change, habitat alteration, invasive species, and pathogens

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	✓
Puget Sound and Georgia Basin	✓
California Current #1	
California Current #2	✓
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	
Arcata Workshop	

Research and model the vulnerability and response of forage fish to climate change, habitat alteration, invasive species, and pathogens

Forage fish perform many ecological roles in the coastal ecosystem and are a key link between the primary producers they consume and the birds, larger fish, and other higher trophic level species that

109 Forage fishes found in the NPLCC region include sardines, anchovy, Pacific herring, surf smelt, longfin smelt, Pacific sand lance, capelin, eulachon, Atka mackerel, and juvenile walleye Pollock (NOAA 2012b, Penttila 2007). For information on the ecological and economic roles of forage fishes and vulnerability to climate change effects, see (for example) Beamish et al. (2009), Krueger et al. (2010), Lellis-Dibble et al (2008), and Penttila (2007).

consume them. In addition, the health and abundance of forage fish populations is one factor in fisheries management decisions for Pacific salmon and other species. For example, current and projected climate change effects on forage fishes such as reduced habitat, increased susceptibility to invasion and disease, and changing predator-prey relationships complicate the determination of allowable harm:

> *…follow up on forage fish theme – climate variability has a significant role in applying pressure on the effective recovery rate including on fish. So it is hard to say what kind of allowable harm to implement…If we can't predict what the runs will look like it is hard to set guidelines for allowable harm (British Columbia Coast Marine).*

Given their ecological and economic importance, and their vulnerability to climate change and other stressors, research and modeling of habitat loss, food web impacts, and invasive species interactions was suggested.

Research on habitat loss

Forage fish habitat is declining in some areas. In Alaska for example, *the beaches are eroding rapidly in areas that are important for things like capelin spawning (Southcentral and Southeast Alaska Marine).* In anticipation of future habitat loss, researchers in British Columbia are already documenting the tidal range of forage fish spawning, egg deposition, and incubation ―*…to demonstrate the degree to which these species are vulnerable to habitat space reduction in the face of present-day armoring, and the expected foreshortening of spawning habitat with sea-level rise" (Survey Respondent 9).* Additional research is suggested to:

- ―*…document the full extent of forage fish spawning seasons and sites within the entire ‗Salish Sea'…and impacts of increased UV exposure on incubating forage fish eggs" (Survey Respondent 9)*.
- Understand grazing impacts on eelgrass. The erosion associated with increased grazing could affect food and prey for forage fishes and birds. To assess these potential impacts, the initial focus should be in locations where rapid sea-level rise is occurring or is projected, at both the watershed and broader NPLCC-scale as appropriate (Portland workshop).

Research results can then inform development of best management practices and regulatory requirements for a range of conservation and restoration activities, including ―*…beach restoration, soft-shore bank protection, [and] re-forestation of marine shorelines…" (Survey Respondent 9)*.

Research and modeling of food web impacts and invasive species and pathogen interactions

In light of the complex relationships among forage fish, higher trophic level species, and invasive species, a forage fishes model was suggested as one component of a strategy to address climate change and maintain functional integrity in the marine ecosystem:

> *It might be nice to have a forage fish model. The higher and secondary production will be impacted by climate change. This will help us also look at keystone species which are important…We should be focusing on maintaining functional integrity instead of balance (British Columbia Coast Marine).*

Research topics include investigation of food web interactions with seabirds and assessing current and potential impacts from pathogens:

> *I am thinking a little farther off shore in terms of data for sea birds and the sea food web…Food web interactions for seabirds farther offshore and impacts on forage fishes (California Current Marine #2).*

> *…from scientific perspective is the impact to forage fish species, in particular the parasites that are infesting the juvenile salmon and herring (Puget Sound and Georgia Basin Marine).*

The final research topic identified by project participants is to assess food chain and forage fish impacts from invasive species (Portland workshop). The assessment would inform fisheries and endangered species management in the southern half of the NPLCC. The sense of urgency is relatively high. However, there are few potential partners and they are widely dispersed geographically:

- Ron Heintz (NOAA National Marine Fisheries Service) studies the nutritional ecology of forage species, including fishes and is one potential partner.
- Mayumi Arimitsu and John Piatt (U.S. Geological Survey, Alaska Science Center) study forage fish, seabirds (which prey on forage fish), and oceanography and were suggested as potential partners. Recent studies include seabird prey community dynamics in glacial fjords of Alaska, status and distribution of Kittlitz‟s Murrelet in southern Alaska, and global seabird responses to forage fish depletion.

Additional information on invasive species and pathogens is provided in Chapter IX.1 (p. 168).

3. Identify focal indicators to track climate change and assess management options

Project participants from throughout the NPLCC region, particularly those working in terrestrial ecosystems, suggested a focus on identifying climate-resilient focal indicators and assessing management options. The focal indicators identified emphasize functional, obligate biophysical and ecological relationships that are key determinants of the overall health and resilience of the ecosystem. Management options to assess include those pertaining to management of threatened and endangered species, state or U.S. Forest Service species of concern, and potential tradeoffs among short- and long-term management options. The suggested activities are:

- Identify climate-resilient focal species and habitat indicators
- Conduct habitat assessments and develop habitat criteria models
- Develop a decision-support tool to assess management options and tradeoffs over time

Many of the suggestions in the first two activity areas are echoed in Chapter VII.2 in the section titled "Conduct research and climate change vulnerability assessments on the biodiversity and ecology of island ecosystems."

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	
California Current #1	
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	✓
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	✓
In-person Workshops	
Portland Workshop	
Juneau Workshop	✓
Arcata Workshop	✓

Identify climate-resilient focal species and habitat indicators

Project participants from throughout the NPLCC region, especially southeast Alaska and northwestern California, requested identifying biophysical and biological focal species and habitat indicators that are resilient to climate change effects (Juneau workshop, Arcata workshop). The indicators would focus on keystone species and the ecological role they fulfill (Juneau workshop, Arcata workshop). In southeast Alaska, particularly the island archipelago system, project participants recommended small mammals such as red-backed voles and flying squirrels as indicator species (Juneau workshop). In northwest California, amphibians such as salamanders were suggested (Arcata workshop).

Focal indicators would inform multi-species management and build resilience for the whole ecosystem (Arcata workshop). For example, flying squirrels are already used as an indicator for wildlife communities in small old-growth reserves in the Tongass National Forest because their abundance is correlated with old-growth forest structure and processes; their ability to migrate within the landscape also depends upon tree spacing, distance between reserves, and other specific habitat requirements (Smith 2005, Smith and Person 2007, Smith et al. 2011). In northwest California, salamanders are a potential focal indicator because they are sensitive to warming, and the invertebrates they consume are a primary determinant of the amount of leaf litter (Clayton et al. 2005, Welsh & Droege 2001). Leaf litter, in turn, affects how much soil is built and therefore the ability of the forest to sequester carbon (Arcata workshop). In addition to identifying the types of decisions focal indicators would inform, Arcata workshop participants also identified two types of management actions that should be taken:

- Conduct follow-up monitoring for the keystone species and focal indicators identified. For example, if there was a prescribed fire, did it negatively affect critical species?
- Manage the forest in a resilient, healthy state. For example, salamanders contribute to the carbon cycle and are a good indicator of the ability of the forest to sequester carbon. A loss of salamander populations negatively affects the forest‟s ability to sequester carbon.

Arcata workshop participants suggested a number of guiding principles to use for identifying climate-resilient focal species and indicators:

- Incorporate information on ecosystem dynamics and population trends. See Chapter VII.2 (p. 128) for additional information on ecosystem dynamics.
- Address how to maintain biodiversity.
- Although it is common to think of species indicators, focal indicators do not all have to be species. For those that are species:
    - Identify the habitats, other requirements for a healthy population, geographic scale, and vulnerability for each.
    - When identifying keystone species and associated focal indicators, include multiple indicators. For example, for salamanders in the forest, include moisture regime or moisture threshold in addition to population numbers. Cloud formations are indicators for migratory birds.

These principles would address key challenges associated with managing species and habitats in light of climate change effects. These include a lack of understanding of how climate change drivers affect ecosystems, habitats, and species, as well as the challenges of generating small-scale projections to use in management activities:

> *The largest lack of information in the southeast [of Alaska] is how temperature and other aspects of climate change impact biology. How do temperature and hydrologic changes affect species? We must understand relationships between drivers and systems. We must translate science to on-the-ground work. Much of what we know are large scale predictions and what managers need are small scale predictions (Alaska and British Columbia Coast Freshwater).*

The sense of urgency is high because these changes have been observed for several decades, but little action has been taken to prevent drastic changes (Arcata workshop). For example, tribes in Alaska recorded changes fifty years ago, but no action was taken and similar changes are now occurring in southern regions of the NPLCC such as coastal northwestern California (Arcata workshop).

The spatial scale should be the biophysical setting and should be able to capture species that can shift as habitat changes in the short-term (i.e., biological time, not geologic time), as well as those that are unable to migrate in the short-term. The temporal scale should extend from 150 years ago to the present and emphasize continual, intergenerational information (Arcata workshop). It will be important to identify an appropriate baseline in order to determine success as climate continues to change. Determination of a baseline would include a discussion of the pros and cons of trying to restore a condition that has existed in recent history (i.e., years and decades ago) while the overall ecosystem is moving toward conditions characteristic of earlier geologic time periods (e.g., 35 million years ago) (Arcata workshop).

Several potential partners and ongoing efforts were identified:

- National effort under the 2009 FLAME Act (the Federal Land Assistance, Management, and Enhancement Act of 2009). Their Phase 2 National Report (PDF, 7.1 MB) is published on www.forestsandrangelands.gov. They are now entering into Phase 3, which will focus on alternative and range measures.
- The Geos Institute and partners projected changes in the distribution of thirteen focal species over two time periods (2040-2069, 2070-2099) under the A2A and A1B emissions scenarios compared to a 1950-2000 baseline. Focal species assessed include two threatened bird species (northern spotted owl, *Strix occidentalis caurina*; marbled murrelet, *Brachyramphus marmoratus*) and Sitka black-tailed deer (*Odocoileus hemionus sitkensis*), which is a culturally-important species (DellaSala et al. *in review*; see DataBasin for more information). Eight conifer species and two epiphytic lichens were also assessed (see Chapter VII.1, p. 123 for a list).
- The NPLCC has partnerships with everyone within the temperate rainforest and is geographically based.
- Tribes are potential partners because their livelihood and culture are based on the land. The Karuk Tribe is engaged in a collaborative partnership with several universities including the University of California Berkeley, Whitman College, University of Oregon, and Humboldt State University. This is a partnership between academia and traditional knowledge holders.
- Regional Fire Science Consortia, such as the California Fire Science Consortium, provide a local perspective.
- U.S. Forest Service Research Stations hold a large amount of data on a large geographic scale. Climate Science Centers are another source of information.
- Citizen science

Conduct habitat assessments and develop habitat criteria models

The suggestion to assess current habitat conditions and develop habitat criteria models was made by several project participants, particularly those working in Alaska and California. In conjunction with the habitat assessments, project participants also suggested identifying historical carrying capacity and comparing the results to the current habitat conditions (Arcata workshop). Similar to the previous section, habitat assessments and habitat criteria models would inform multi-species management and build resilience for the whole ecosystem (Arcata workshop). For example, understanding the use of key habitats (e.g., coldwater refugia, nearshore rearing areas) by potential indicator species (e.g., salmonids, aquatic invertebrates) would inform Subsistence, recreational, and commercial use decisions and improve understanding of the ecological effects of changing surficial flows and water chemistry on species and habitats (Juneau workshop).

Habitat assessments would address the lack of information on habitat requirements for some species (Juneau workshop, Arcata workshop). For example, habitat information for generalists such as bears or for species affected by a few factors (e.g., herpetofauna: amphibians and reptiles) is available, but for many species (e.g., small mammal species) information is lacking (Juneau workshop, Arcata workshop). Habitat criteria models would provide information about how the environment may change and how multiple changes may integrate to determine the future health and resilience of the ecosystem (Arcata workshop).

Project participants suggested conducting the assessments and developing the models as soon as possible in order to inform preventative decisions for the landscape (Arcata workshop). A nested spatial scale extending from the headwater areas to ocean waters and including the biophysical scale was suggested; the temporal scale should be continual and intergenerational, and include seasonal and annual changes in the ecosystem (e.g., hydrologic regimes) (Juneau workshop, Arcata workshop). Potential partners and ongoing efforts include the NPLCC, the Karuk Tribe and their university partners (University of California Berkeley, Whitman College, University of Oregon, and Humboldt State University), Climate Science Centers, regional fire consortia (e.g., California Fire Science Consortium), citizen science, and U.S. Forest Service Research Stations.

Develop a decision-support tool to assess management options and tradeoffs over time

Project participants working in terrestrial ecosystems identified a range of challenges and opportunities associated with managing ecosystems, habitats, and species in the short- and long-term given current and potential future climate change effects. To address the challenges, project participants suggested a tool to support management decision making would be helpful:

> *… It would be helpful to have any sort of tools that can help us strengthen [our] analyses, or even outreach to the public to get them to understand what we're doing. And then maybe prioritization tools for tradeoffs of…short-term effects vs. long-term benefits. How would you look at the landscape to maintain and address both long and short term needs?… (Interior Mountain Ecosystems).*

> *…I am thinking of a linkage of individual species needs with global climate models that could work at a local level for species that have a local effect…I'm thinking of species that are localized and endemic to an area, and getting a modeling system for a local area into the hands of those doing the consultations to enable them to look at the longer-term effects of climate change as well as whatever the agency action being considered is – linking those up I think would be huge (Interior Mountain Ecosystems).*

> *If I could highlight one thing you said that resonated with me, it may not be just a model itself but a communication tool that enables those doing the consultation to connect with climate change experts that might be able to provide better information to those people on a regular basis as they're doing the consultations… (Interior Mountain Ecosystems).*

Such a tool would inform management practice including ESA consultation and development activities across NPLCC landscapes, particularly forests (Juneau workshop, Arcata workshop). Some project participants indicated the sense of urgency was "immediate," while others simply stated the tool would be very useful (Juneau workshop, Arcata workshop).

Several guiding principles to inform assessments of short- and long-term management options and tradeoffs were suggested by Arcata workshop participants:

- Adapt to changes to be flexible to unexpected climate change (Arcata workshop).
- Consider how to plan for the present and add resilience for the future. Consider the question: How do we think about tradeoffs between restoration and resilience in the future? (Arcata workshop).
- Work toward a whole ecosystem approach. Examples include multi-species management, active management to help communities transition, and flexibility of local management. In addition, use indicators such as those described earlier in this section (p. 158) to track the state of different processes. For example, to inform decisions about when to burn in spring, track the timing of key species migrations such as migratory birds and burn when they pass through the landscape (Arcata workshop).
- Pursue place-based management if it is beneficial for the ecosystem and focus on local responses to see if the biological community will be able to adapt. For example, consider management tradeoffs on north-facing *versus* south-facing slopes, or on particular areas such as national parks or tribal lands (Arcata workshop).
- Preserve habitat for key species or resources by finding refugia. See Chapter VII.2 (p. 128) for more information on refugia (Arcata workshop).
- Move beyond current management practices to facilitate situations in which various management perspectives (e.g., traditional ecological knowledge, western science) align.

By incorporating these guiding principles, the decision-support tool would respond to the ecological, management, and social challenges identified by project participants. The primary ecological and management challenge is to balance the short-term needs of key species with long-term needs or threats:

> *… from the wildlife perspective, it is a challenge to balance the short-term needs of species, especially species of conservation concern or threatened and endangered species…while also looking at the long-term needs or threats including climate change and other stressors… (Interior Mountain Ecosystems).*

> *While we try and do fuel reduction projects, we also have to maintain habitat for the species that we focus our management on – threatened and endangered species, Forest Service Sensitive species – a lot of those are species that like having understory so it is kind of at odds there. You need to maintain habitat for those species in the short-term, but if you don't do something, that habitat will be lost in the long-term via fire. That challenge is going to get worse and worse with climate change and other stressors... (Interior Mountain Ecosystems).*

A secondary management challenge is *budget cycles…that don't necessarily allow us to be as thoughtful we'd want to be in those processes (Interior Mountain Ecosystems).* The social challenges include balancing the preferences of those who support different management actions and overcoming public pressure to choose a particular management action over another:

> *…we also have people who want more fire – there are fire-associated species such as black-backed woodpecker – they don't want us to do any fuel reduction because they want more fire on the landscape. And they don't want us to do anything on the landscape once it burns… (Interior Mountain Ecosystems).*

> *…the public pressure is an additional challenge. We end up being challenged – we identify a priority project, but people don't want us to do it because they don't like the short-term effects or they don't believe in the long term benefits of the project… (Interior Mountain Ecosystems).*

The spatial scale for the decision-support tool is NPLCC-wide, but with a focus on key species such as spotted owl, anadromous fish species, wolverine, or other species of concern including threatened and endangered species (Interior Mountain Ecosystems). For example, a decision-support tool to assess management options and tradeoffs would be helpful for species such as wolverine that are not currently listed under the ESA but are nonetheless vulnerable:

> *When I hear endangered species in this landscape and terrestrial species, I think of species like wolverines that were warranted but not listed. That's a real challenge when you think about the impacts our actions – especially when you talk about recreation management in some of the more alpine areas – how we're going to impact that species over time could use some real work… (Interior Mountain Ecosystems).*

The temporal scale would vary, but should include the 10-year scale in which some participants engage with consultations:

> *The consultations I'm used to are on 10 year scale. Being able to set us up for longer term thinking… could help offset some of the climate effects on particular species…[and the decision-support tool or model] would enable us to put some of that information in the consultations and be able to defend them… (Interior Mountain Ecosystems).*

Potential partners and ongoing efforts to assist with development and implementation of the decision-support tool were not identified specifically. However, several potential partners for threatened and endangered Species Management were suggested. They include U.S. FWS, the U.S. Forest Service, the Alaska Department of Fish and Game, and British Columbia ministries.

4. Develop maps and models to address climate change effects on other key fish species

Portland workshop participants identified two broad activities for addressing climate change impacts on key fish species:

- Develop downscaled data particular to address climate change effects on key fish species
- Develop models and vulnerability maps for changes in fish habitat

These suggestions are applicable to the Pacific salmon, other anadromous fishes, and forage fishes discussed earlier in this chapter (see Sections 1, p. 150 and 2, p. 155, respectively), as well as other fishes that may emerge as key species as the NPLCC continues to develop and its members and stakeholders continue to determine priorities.

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	
British Columbia Coast	
Puget Sound and Georgia Basin	✓
California Current #1	
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	
Interior Mountain Ecosystems	
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	
Arcata Workshop	

Develop downscaled data to address climate change effects on key fish species

Downscaled hydrologic (e.g., streamflow), air temperature, and stream temperature models, as well as spatial datasets (e.g., hydrology, LiDAR), were identified as an immediate, urgent data gap to fill (0 to 3 years) during the Portland workshop. These gaps are also reflected in the request for a climate-smart sensor and monitoring network (see Chapter V.1, p. 69). Data would be used to inform regulation under the Endangered Species Act (ESA), inform habitat protection, and to prioritize restoration adaptation strategies and actions. Some participants identified the key spatial scale as the reach, while others suggested a NPLCC and watershed basin-wide spatial scale. In the case of spatial datasets, LiDAR is available along the Oregon coast, but not at low-tide. A seasonal temporal scale was suggested, with a focus on vulnerable seasons or seasons with peak abundances. Alec Maule (U.S. Geological Survey, Western Fisheries Research Center) is a suggested partner for assistance with integrated modeling and climate change effects on fish physiology.

Develop models and vulnerability maps for changes in fish habitat

To inform the prioritization of restoration adaptation strategies, Portland workshop participants suggested the development, in three to five years, of models of habitat change due to altered temperature and flow regimes, sea-level rise, storm surge, and other factors. To inform fish models and prioritization efforts, one web-based focus group participant stated that vulnerability maps are useful because they allow users to *see that some areas will not be impacted (Puget Sound and Georgia Basin Marine).* For example, it would be useful to design a multi-spatial scale vulnerability map that includes key factors such as water temperature and can easily be used in a fish model:

> *…[Vulnerability maps of] large basin[s] with some appropriate smaller level[s] for certain climate change endpoints like water temperature that can feed easily into a fish model. Those types of maps seem to resonate well (Puget Sound and Georgia Basin Marine).*

To inform ESA regulation and recovery, complementary research at the reach, basin, and watershed population scale was suggested to understand habitat changes with uncertainty and to understand the linkage between habitat changes and species genetic response. Research to investigate how population-level climate change stressors will affect available refugia at the range, sub-NPLCC, and NPLCC-scale was also suggested as a one to three year research focus.

Numerous federal partners were identified (U.S. FWS, U.S. Forest Service, BLM, NPS, NOAA Fisheries, USGS), as well as coastal watershed groups and state and tribal fish, wildlife, and related resource agencies.

IX. Activity Areas for Invasive Species, Pests, Pathogens, and Disease

Invasive species, pests, pathogens, and disease were discussed in some web-based focus groups (Puget Sound and Georgia Basin Marine, Southcentral and Southeast Alaska Marine), but did not emerge as a commonly stated topic for further discussion. However, participants in all three workshops identified this topic as a potentially important information gap, and in the Portland and Juneau workshops, participants selected it as a topic to be explored in more detail in their break-out groups.

Similar to the discussion of forage fishes, invasive species, pests, pathogens, and disease tended to be subsumed under larger-scale topics during the workshops, despite the fact they are identified as an important topic to address across the NPLCC region. For example, during the Arcata workshop, participants discussed at-length how to incorporate invasive species into the list of discussion topics, but no one joined the group because other topics (especially changes to fog and disturbance regimes and resulting effects on forest health) were more popular.

The activity area for invasive species, pests, pathogens, and disease is:

1. Support efforts to identify the corridors invasive species, pests, pathogens, and diseases are likely to use in response to changes in climate

In discussions of invasive species, pests, pathogens, and disease, three common themes emerged:

- The NPLCC region, particularly the marine waters, is a corridor in which invasive species could "march on up." (Southcentral and Southeast Alaska Marine)
- The integrated effects of climate change, land use, invasive species, and pathogens may induce significant changes to forest composition and the linked terrestrial-aquatic ecosystem. Vegetation management strategies should be developed to respond to actual and potential changes.
- The integrated effects of climate change, related stressors, invasive species, and disease on indigenous natural and cultural resources is of particular concern for Tribes and Alaskan Natives, who depend on existing species and community compositions for their Way of Life.

The first and second themes are elaborated upon in this chapter. The third theme is addressed briefly in this chapter and in greater detail in Chapter IV: Activity Areas for Indigenous Natural and Cultural Resources (p. 54).

Within an activity area, several specific activities requested by project participants are described. The description includes information on how many project participants identified the activity and the climate change-related challenges associated with pursuing the activity. To provide information to the NPLCC about when, where, and under what circumstances support is requested, participant evaluations of the activity across the four evaluation criteria are synthesized:

- *Decision-relevance* indicates which decisions the activity would help inform or guide.
- *Timeline or sense of urgency* indicates when the activity is needed and provides a sense of why and how important, or urgent, it is to pursue the activity.

- *Spatial and temporal scale* identifies the necessary geographic region or spatial coverage for the activity and whether the activity is needed on an annual, seasonal, daily, etc. timescale.
- *Partners and ongoing efforts* identifies the people, partnerships, and organizations that might already have information about the activity or might be well suited to develop it.

1. Support efforts to identify the dispersal corridors invasive species, pests, pathogens, and diseases are likely to use in response to changes in climate

Project participants described invasive species, pests, pathogens, and disease as an overarching management stressor. Whether they were fish biologists, forest hydrologists, or marine ecologists, invasive species, disease, and pathogens were described consistently as an important factor that complicates resource management decision making. The terrestrial landscape and marine waters of the NPLCC region were identified as potential avenues for invasive species, pests, pathogens, and disease to move northward. The emphasis was on marine waters as a dispersal corridor:[110]

> *LCC waters are the corridor for marine invasives to be travelling. (Southcentral and Southeast Alaska Marine)*

The current northward movement of the mountain pine beetle outbreak, which is largely outside of the NPLCC region to-date, indicates invasive species may also migrate northward in terrestrial ecosystems. Acknowledging that efforts to detect, control, and eradicate invasive species are often devolved to state, county, or local government, a range of research-based to management-based activities were suggested to better identify, understand, and track the movement of invasive species across the NPLCC"s many political boundaries:

- Study the genetics of species hybridization
- Model invasive species and disease relationships
- Develop research partnerships to study fish and bird disease
- Assess habitat and resource vulnerability to changing patterns of invasion and disease
- Model adaptive management outcomes

Incidence of Discussion of Activity Area in the Web-based Survey, Web-based Focus Groups, and In-person Workshops	
Web-based Survey	
NPLCC-wide	✓
Marine Ecosystem Web-based Focus Groups	
Southcentral and Southeast Alaska	✓
British Columbia Coast	
Puget Sound and Georgia Basin	✓
California Current #1	✓
California Current #2	
Freshwater Ecosystem Web-based Focus Groups	
Alaska and British Columbia Coast	
Pacific Coast and Nass Ranges	✓
Puget Sound and Georgia Basin	
Columbia River Basin	
WA/OR/n. CA Coastal Ranges and Drainages	
Terrestrial Ecosystem Web-based Focus Groups	
Coastal Temperate Rainforests	
Lowlands, Prairies, and Other Non-forested System	✓
Interior Mountain Ecosystems	✓
In-person Workshops	
Portland Workshop	✓
Juneau Workshop	✓
Arcata Workshop	

[110] A *dispersal corridor* is a specific type of habitat corridor and refers to one-way movements of individuals or populations from one area to another (Meiklejohn et al. 2009).

Study the genetics of species hybridization

Participants stated that climate change may redefine the notion of native, non-native, and invasive species, as well as the species classification. Beginning with a few carefully selected cases, research to understand how species hybridize at the genetic level would help articulate these definitions. The information is "moderately urgent." It would inform Endangered Species Act policy and management, shoreline management, and would be relevant for informing the public about potential species changes. The information could also inform efforts to refine legal and regulatory definitions of "species" in ways that incorporate transition and adaptation. The relevant spatial scale is NPLCC-wide. Partners should be selected according to the specific cases chosen for investigation. The specific cases should be chosen by a diverse stakeholder group.

To store information about species hybridization, movement, and other factors, Portland workshop participants identified development of a West-wide database on invasive species and pathogens as a moderately urgent project to pursue. A database would be useful for fish and wildlife managers, particularly those working on the Endangered Species Act and quarantine policy for invasive species. The spatial scale is West-wide, from Alaska to California and points inland. The database should be kept current. Potential partners and ongoing efforts to assist with the database include:

- Invasive species councils are currently developing databases. For example, there is a National Invasive Species Council, as well as state councils for Washington, Oregon, and California and an invasive species working group in Alaska.
- The Aquatic Invasions Research Directory (AIRD) is a "free database designed to promote information transfer, coordination, and collaborative research on the invasion of aquatic ecosystems. AIRD contains current information on people, research, technology, policy and management issues relevant to aquatic invasions."
- The National Estuarine and Marine Exotic Species Information System (NEMESIS) includes information on approximately 500 introduced marine and estuarine species of algae and invertebrates. It is specific to established populations in the continental United States.
- Mark Sytsma (Portland State University) was suggested as a potential partner for invasive species databases. Other ongoing projects include the limnology of Waldo Lake (located in the Cascade Mountains), aquatic plant surveys in Pacific Northwest lakes, invasive species in the Columbia River, dreissenid mussel monitoring in western states, *Spartina* management in Oregon estuaries, and invasive species policy.
- Greg Ruiz (Smithsonian Environmental Research Center, Marine Invasions Research Lab) works on marine invasive species (e.g., invasion biology, ecological parasitology), monitoring, and databases.

Model invasive species and disease relationships

Both the Southcentral and Southeast Alaska Marine web-based focus group and Portland workshop participants suggested improved or increased modeling of changes in invasive species and disease relationships would be helpful for understanding the potential spread of invasive species and disease. For example, as sea surface and stream temperatures increase, New Zealand mud snail, Japanese knotweed, orange hawkweed, and whirling fish disease may be dispersed to new areas via ballast water dumping, contaminated boat propellers, or on shoes and clothing where conditions are more conducive to new establishment or increased spread (Juneau workshop). Appropriately designed models could inform specific decisions about sensitive species, quarantine policy, and disinfection. Modeling is moderately important to very important to undertake, with a timeframe for completion in the next five to ten years. Specific models of species distributions, populations, food chains, and the susceptibility of marine habitats to invasion risk were suggested. For example:

> *I would broaden it to say that freshwater input and nearshore temperature because those two are the core in the niche models for the Alaska nearshore models for marine invasive species. I see the NPLCC being (marine waters) the corridor in which these invasives will ‗march on up'. There is so much coastline but it is important to know where we should focus on new invasions (Southcentral and Southeast Alaska Marine).*

Participants suggested a NPLCC-wide spatial scale for models, which should be guided by high priority issues identified by the database and researchers in the region. Key research partners include groups with landscape capability (U.S. Forest Service and U.S. Geological Survey) and post-doctoral researchers.

Develop research partnerships to study fish and bird disease

As air and water temperatures warm, some fishes and birds may be more susceptible to disease. For example:

> *…the impact to forage fish species, in particular the parasites that are infesting the juvenile salmon and herring (Puget Sound and Georgia Basin Marine).*

> *…one concern that we would have is fish disease and how it is affected by temperature variation in the basin. Again going back to this issue of water availability but also the thermal loading and not just how it affects water availability but also water temperature in the river in terms of affecting disease transmission. On that note there are also concerns of avian diseases in the upper basin with respect to for water fowl in the wetlands which also is related to the issues of water availability and temperatures (Lowlands, Prairies, and Other Non-forested Systems).*

Portland workshop participants suggested a NPLCC-wide research partnership among federal, state, and tribal fisheries, aquatic researchers, and biomedical researchers to understand the potential effects of increased air and water temperature on fish diseases. The partnership is moderately urgent to develop and would be relevant for subsistence users, commercial fisheries, the management of engineered rivers, and Endangered Species Act restoration and recovery.

The research partnership should cover the NPLCC region and focus on future time periods. Potential partners include federal, state, and tribal fisheries, aquatic researchers, biomedical researchers, and other researchers and managers. For example:

- The Invasive Tunicate Network (itunicate) monitors for "non-native tunicates and other invasive species along the U.S. West Coast, with a primary focus on Alaska."

- James Winton (U.S. Geological Survey, Western Fisheries Research Center) leads "a team of scientists, technicians, post-doctoral researchers, graduate students and visiting scientists working to improve methods for the detection of fish pathogens, determine factors affecting the epidemiology of fish diseases, and develop novel control strategies for reducing losses among both hatchery-reared and wild fish."
- Ted Meyers (Alaska Department of Fish and Game) is State Fish Pathologist and was suggested as a potential partner for information on salmon disease ecology.
- Jill Rolland (U.S. Geological Survey) was suggested as a potential partner for information on fish and mammal diseases and is the Director of the Western Fisheries Science Center.
- Jonathan Sleeman (U.S. Geological Survey National Wildlife Health Center, Director) specializes in the epidemiology of wildlife diseases and was suggested as a potential partner for information on bird and mammal diseases.
- Kevin Lafferty (U.S. Geological Survey, Western Ecological Research Center) is a Research Ecologist and was suggested as a potential partner for information on disease ecology, with an emphasis on marine ecosystems.
- Patti Bright (U.S. Geological Survey) was suggested as a potential partner for information on environmental health.

Assess habitat and resource vulnerability to changing patterns of invasion and disease

Project participants identified a range of habitat and resource vulnerabilities to changing patterns of invasion and disease in aquatic and terrestrial ecosystems. This activity informs questions such as:

- Are there current (or predicted) invasive species, or endemic disease or pathogens that are likely to increase due to rising temperatures and changing precipitation patterns in southeast and southcentral Alaska? (Juneau workshop)
- Are subsistence resources going to be impacted by the changes brought about because of invasive species, diseases, and pathogens? (Juneau workshop)
- How will land use decisions made in response to beetle outbreaks affect forest hydrology? (Pacific Coast and Nass Ranges Freshwater)

The latter is an important question in British Columbia currently, where the province‟s carbon emissions standards will not allow the burning of trees infested with mountain pine beetle. Instead, these trees are being harvested and the effect on forest hydrology and health across the ecosystem is unknown:

> *We need to also deal with issues of land use change. One example is the impact of the pine bark beetle. There are large areas that are currently being harvested to deal with the beetle (cannot burn the trees because of the emissions produced in burning). There is little knowledge on how this land use change will impact hydrology in the area. To summarize, connect terrestrial with aquatic through sediment analysis: pine beetle [outbreak leads to] harvesting at landscape scale,[which means] more soil lost to stream. [The resulting] low flow, nutrients, and pollutants [lead to] large landscape change, both due to pine beetle's impact on forest health and landscape change as a result of increased harvest (Pacific Coast and Nass Ranges Freshwater).*

The vulnerability of habitats and resources would affect a family‟s ability to utilize traditional resources for food, shelter, or other needs. This is a potential threat to the Indigenous Way of Life. It would also affect decisions about resource allocation for subsistence, commercial, and recreational use. Further, an improved understand of vulnerability would inform decisions about where to focus control and eradication efforts, protected area management, and other regulatory decisions. The sense of urgency depends on the community and the invasive species, disease, or pathogen in question. For some invasive species, pathogens, and diseases, it could be more urgent on a local level. For others, it could be a 10-, 20- or 50-year outlook with a regional or subregional focus.

Assessments should be targeted to high-priority sub-regions or particular habitat types, then expand to the NPLCC geography. Temporal perspectives at the 10-, 50-, and 100-year marks are suggested. For example:

> *We need to investigate potential effects of climate change on invasive species in tidal wetlands. Climate change will disturb existing ecosystems; such disturbance is likely to enable establishment of invasive species that have previously failed to gain a foothold (California Current Marine #1).*

In northwest California forests, an increase in insect-induced mortality has been observed, although the extent is less than in other regions of western North America:

> *We do have an increase of insect mortalities, it‛s not on the scale of the northern Rockies and it‛s somewhat localized in Southern California forests (Interior Mountain Ecosystems).*

Participants suggested incorporating these assessments into broader vulnerability assessments planned or ongoing in the region, which would be useful and relevant for land and water managers, protected area management, and for informing other regulatory decisions. In northern latitudes, potential partners include:

- U.S. Forest Service, specifically State and Private Forestry and the Forest Health Protection Unit
- University of Alaska Fairbanks
- State of Alaska Department of Natural Resources and Division of Forestry
- Bob Piorkowski (Alaska Department Fish and Game, Freshwater Fish, Aquatic Plants, Amphibians and Ornamental Fish program) is the Fish Resource Permit Program Coordinator and was suggested as a potential partner for invasive species work in the NPLCC region.

In the southern latitudes, potential partners include:

- Lars W. J. Anderson (USDA Agricultural Research Service, *Retired*) works on the biology, ecology, and management of aquatic weeds and focuses on reproduction and invasiveness of exotic species.
- Steve Bollens (Washington State University Vancouver) investigates the ecology of marine and estuarine zooplankton and fish and was suggested as a potential partner on nearshore and marine invasive species. Locations of current or recent projects include the estuaries of British Columbia, Washington, Oregon, and California.

- Timothy Counihan (U.S. Geological Survey, Lead Research Fishery Biologist) was suggested as a potential partner for information on Columbia River monitoring (Washington and Oregon).

For information on the effects of marine ballast water, the following researchers were suggested:

- Scott S. Smith (U.S. Geological Survey, Western Fisheries Research Center) is a Supervisory Research Biologist and is developing ballast water treatment technologies.
- Jeff Cordell (University of Washington) published on the species composition of marine ballast water and studies the role of exotic invertebrates in Pacific Northwest estuaries.
- Russell Herwig (University of Washington) studies the "introduction of non-indigenous aquatic organisms, including microorganisms, in ballast water," as well as "development of ballast water treatment technologies than can be used to control the introduction of non-indigenous organisms and the development of technologies to measure viable organisms present at the extremely low concentrations found in treated ballast water."
- Richard Everett (U.S. Coast Guard) is a member of the Pacific Ballast Water Group within the Pacific States Marine Fisheries Commission and was suggested as a potential partner for information on treatment and regulations related to marine ballast water.

Model adaptive management outcomes

To inform and advance adaptive management in an era of climate change, Portland workshop participants suggested modeling adaptive management outcomes to assess results and rank further actions over the next five to ten years. Modeling outcomes would guide emergency response efforts for sensitive species, conservation planning, vegetation management, and invasive species policy, and is considered a moderately urgent activity to pursue by workshop participants.

The model would first be targeted toward high priority systems before expanding to the entire NPLCC region. For example, it would inform decisions about which trees to plant given current and potential future disease and insect outbreaks:

> *In forests should we be planting other types of trees? We currently have monoculture pine forests in areas that are susceptible to disease. There are disease and bug outbreaks (pine beetle. Also Dopostroma – ―pine needle blight" – spreads better with warmer, wetter fall). How do we make sure that we have healthy and diverse forests in the future? We should be looking at predictive models to figure out what might be a good species (Pacific Coast and Nass Ranges Freshwater).*

While there are many potential partners, one specific example is to partner with state and federal management agencies such as U.S. FWS to develop, in the next five to ten years, a prioritization model to guide emergency response efforts for sensitive species, conservation planning, and invasive species policy. Paul Heimowitz (U.S. FWS, Pacific Region Aquatic Invasive Species Program Co-Coordinator) "implements regional aquatic invasive species prevention, detection, and management programs" and was suggested as a potential partner for invasive species management.

X. Conclusion

Assessments of the climate change adaptation needs of conservation, climate change, and resource management professionals are increasing in number and availability, particularly for marine and coastal ecosystems. However, a nuanced understanding of these practitioner needs still lags behind similar knowledge of physical and ecological climate change impacts. This assessment contributes to the understanding of challenges, needs, and opportunities associated with advancing climate change adaptation, conservation, and sustainable resource management in at least three ways. First, this assessment is the first of its kind to focus specifically on the NPLCC region and its unique cross-boundary roles within the international and multi-jurisdictional geography covered by the region. Second, within this context, this assessment takes a multi-ecosystem approach, identifying practitioner challenges, needs, and opportunities within marine, coastal, freshwater, and terrestrial ecosystems. Information on freshwater and terrestrial ecosystems is provided for the first time, while information on marine and coastal ecosystems is supported by similar practitioner needs assessments focusing on coastal ecosystems. Third, the assessment includes specific requests made by tribal members and representatives that would address challenges, needs, and opportunities for responding to climate change impacts on the Indigenous Way of Life.

The needs described in this assessment will evolve over time, as will the activities requested to meet those needs. We encourage repeating this assessment to evaluate which needs have been met, which needs have not been met, and the effectiveness of requested activities in responding to the identified needs. Similarly, as some needs are addressed and climate change impacts begin to manifest in new ways, reevaluation may identify novel needs.

Over the next year, NWF will convene workshops in conjunction with the NPLCC to focus on one or more strategic priorities identified in the NPLCC Strategy for Science and Traditional Ecological Knowledge (2013-2016) and/or associated Annual Work Plans. This assessment will inform the design and facilitation of the workshops. In addition, this report and the overall project have connected NWF with people and resources that will assist with production of a report on climate change effects and adaptation approaches for the NPLCC region‟s terrestrial ecosystems, habitats, and species. In the next year, NWF will also finalize two similar reports that focus on the region‟s marine/coastal and freshwater ecosystems.

XI. Appendices

1. Project Participants

First name	Last name	Primary affiliation
Alan	Parker	The Evergreen State College
Aldaron	Laird	Trinity Associates
Allison	Aldous	The Nature Conservancy - Oregon
Allison	Bidlack	Ecotrust
Allyson	Carroll	Humboldt State University
Andra	Martin	Juneau School District
Andrea	MacLennan	Coastal Geologic Services
Andrea	Woodward	US Geological Survey
Angela	Addison	Ecotrust Canada
Ann	Wyatt	Klawock Cooperative Association
Anna	Buckley	Oregon Department of State Lands
Anne	Shaffer	Coastal Watershed Institute
Barb	Faggetter	Ocean Ecology
Barbara	Schrader	USDA Forest Service
Barry	Hill	U.S. Forest Service
Bill	Hanson	US Fish and Wildlife Service
Bill	Tripp	Karuk Tribe
Bill T.	Peterson	Northwest Fisheries Science Center
Brian	Logan	US Forest Service
Britta	Schroeder	University of Alaska Fairbanks
Bruce	Duncan	US Environmental Protection Agency
Buster	Shepherd	Skagway Traditional Council
C. John	Ralph	U.S. Forest Service
Carl	Markon	US Geological Survey
Carol	McKenzie	USDA Forest Service
Carrie	Phillips	US Geological Survey
Catherine	Corbett	Lower Columbia River Estuary Partnership
Charles	Houghten	U.S. Fish and Wildlife Service
Charles P.	O'Hara	Swinomish Indian Tribal Community
Chris	Lauver	National Park Service
Chris	Toole	National Marine Fisheries Service
Colin	Campbell	Sierra Club BC
Colin	Shanley	The Nature Conservancy - Alaska
Craig	Wightman	BC Conservation Foundation
Curtis	Tanner	WA Department of Fish and Wildlife

Dan	Berman	Humboldt Bay Harbor, Recreation and Conservation District
Dan	Penttila	Salish Sea Biological
Dan	Shively	US Fish and Wildlife Service
Darrin	Sharp	Oregon Climate Change Research Institute
Daryl	Van Dyke	U.S. Fish and Wildlife Service
Dave	D'Amore	US Forest Service
Dave	Roemer	National Park Service
Dave	Wilford	BC Ministry of Forests, Lands, and Natural Resource Operations
David	Graves	Columbia River Inter-Tribal Fish Commission
David	Katzeek	Goldbelt Heritage Foundation
David	Patte	US Fish and Wildlife Service
Deborah	Aseltine-Neilson	California Department of Fish and Game
Dede	Olson	US Forest Service
Dennis	Nickerson	Organized Village of Kasaan
Dennis R.	Lassuy	US Fish and Wildlife Service
Devlin	Fernandes	Ecotrust Canada
Diana	Craig	U.S. Forest Service
Dominick	DellaSala	GEOS Institute
Don	Campton	US Fish and Wildlife Service
Doug	Biffard	BC Ministry of Environment
Doug	Myers	People for Puget Sound
Ed	Johnstone	Quinault Indian Nation
Ed	Warren	Chilkat Indian Village
Edith	Tobe	Squamish River Watershed Society
Edna	Jackson	Organized Village of Kake (Kake First Nation)
Emily	Burns	Save the Redwoods League
Eran	Hood	University of Alaska - Southeast
Eric	Grossman	US Geological Survey
Eric T.	Nelson	US Fish and Wildlife Service
Frank	Shipley	US Geological Survey
Frank	Lake	U.S. Forest Service
Frank	Shipley	U.S. Geological Survey
Ginger	Phalen	US Fish and Wildlife Service
Gordie	Reeves	US Forest Service
Gregory	Collins	California State Parks
Guy	Gelfenbaum	US Geological Survey
Hans	Schreier	University of British Columbia
Hart	Welsh	U.S. Forest Service
Hilary	Papendick	California Coastal Commission
Hussein	Alidina	World Wildlife Fund - Canada

Ian	Miller	Washington Sea Grant
James	Casey	World Wildlife Fund - Vancouver, Canada
Jason	Dunham	US Geological Survey
Jason	Scherr	Prince Rupert Port Authority
Jason	Thompson	Haida Nation
Jeff	Anderson	Northern Hydrology & Engineering
Jeff P.	Hollenbeck	US Geological Survey
Jen	Watkins	Conservation Northwest
Jennie	Hoffman	EcoAdapt
Jennifer A.	Curtis	U.S. Geological Survey
Jesse	Barham	US Fish and Wildlife Service
Jesse	Plumage	U.S. Forest Service
Jessi	Kershner	EcoAdapt
Jessie	Dybdahl	Hoonah Indian Association
Jim	Regan-Vienop	USDA - Natural Resources Conservation Service
Joanna	Ekrem	Washington State Department of Ecology
Joe	Schumacker	Quinault Indian Nation
Joe	Hostler	Yurok Tribe
Joel	Shinn	U.S. Fish and Wildlife Service
John	Crusius	US Geological Survey
John	Takekawa	US Geological Survey
Jon	Martin	USDA Forest Service
Jonna D.	Engel	California Coastal Commission
Judith	Gordon	US Fish and Wildlife Service
Judy	Ramos	University of Alaska Fairbanks
Karyn	Gear	State of California Coastal Conservancy
Kate	Skaggs	Washington State Department of Ecology
Kathie	Dello	Oregon Climate Change Research Institute
Kathleen	Sloan	Yurok Tribe
Kathy	Lynn	University of Oregon
Keith	Hatch	Bureau of Indian Affairs
Kelley	Turner	US Geological Survey
Kelly	Nesvacil	AK Department of Fish & Game
Kerrie	O'Donnell	Ecotrust Canada
Kevin	O'Hara	U.S. Fish and Wildlife Service
Kim	Hyatt	Fisheries and Oceans Canada
Kim	Wright	Living Oceans Society
Lara	Whitely Binder	Climate Impacts Group
Laura	Brophy	Institute for Applied Ecology
Lauri	Vigue	WA Department of Fish and Wildlife
Leaf	Hillman	Karuk Tribe

Leanna	Boyer	Seagrass Conservation Working Group
Leihla	Scharlau	South Sound Estuary Association
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Leonel	Arguello	National Park Service
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Lynn	Helbrecht	WA Department of Fish and Wildlife
Machelle	Edenshaw	Organized Village of Kasaan
Mandy	Lindeberg	National Oceanic and Atmospheric Administration
Mark	Trenholm	North American Salmon Stronghold Partnership
Mark	Wheetley	City of Arcata
Marlow	Pellatt	Parks Canada
Mary	Kennedy	Craig Tribal Association
Mary	Porter	Yakutat Tlingit Tribe
Matthew	Barry	U.S. Fish and Wildlife Service
Melissa	Kraemer	California Coastal Commission
Michael	Kellett	US Forest Service
Michael F.	Sigler	Alaska Fisheries Science Center
Michael J.	Furniss	US Forest Service
Michele	Deakin	Seagrass Conservation Working Group
Michelle	Jesperson	California Coastal Commission
Mike	Ambach	World Wildlife Fund - Canada
Mike	Goldstein	Alaska Coastal Rainforest Center
Monique	Sonoquie	Wiyot Tribe
Nancy	Finley	U.S. Fish and Wildlife Service
Nancy	Munn	National Marine Fisheries Service
Nicole	Athearn	US Fish and Wildlife Service
Nikki	Wright	Seagrass Conservation Working Group
Pat	Warren	Chilkat Indian Village
Patrick	Vaughan	California State Parks
Paul	Brewster	US Forest Service
Paul	Heimowitz	US Fish and Wildlife Service
Paul	Hennon	US Forest Service
Paul	Pickett	Washington State Department of Ecology
Phil	van Mantgem	U.S. Geological Survey
Preston	Hardison	Tulalip Tribe
Rachael	Jamison	WA Department of Natural Resources
Rachel	Gregg	EcoAdapt
Ramona	Butz	US Forest Service
Ramona	de Graaf	British Columbia Shore Spawners Alliance
Ray	Paddock	Central Council Tlingit and Haida Indian Tribes of Alaska
Rebecca	Flitcroft	US Forest Service

Renee	Claggett	Wrangell Cooperative Organization
Richard	Thompson	BC Ministry of Environment
Rick	Edwards	US Forest Service
Rob	DeVelice	U.S. Forest Service
Rob	Jones	Northwest Indian Fisheries Commission
Robert	Vadas, Jr.	WA Department of Fish and Wildlife
Roman	Motyka	University of Alaska Fairbanks
Rosemary	Sherriff	Humboldt State University
Rowan	Baker	US Fish and Wildlife Service
Roy	Lowe	US Fish and Wildlife Service
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Stephen	Kullmann	Wiyot Tribe
Stephen	Zylstra	US Fish and Wildlife Service
Steve	Diggon	Coastal First Nations
Steve	Fradkin	National Park Service
Steve	Litke	Fraser Basin Council
Steve	Robinson	SR Productions
Steve	Smith	US Fish and Wildlife Service
Susan	Schlosser	CA Sea Grant Extension Program
Tanya	Bryan	MarLogic Consulting
Teresa	Gaudette	Organized Village of Kake (Kake First Nation)
Tina	Whitman	Friends of the San Juans
Todd	Brinkman	University of Alaska Fairbanks
Tom	Okey	West Coast Vancouver Island Aquatic Management Board
Tony	D'Andrea	Oregon Department of Fish and Wildlife
Vicki	Finn	US Fish and Wildlife Service
Vicki	Frey	California Department of Fish and Game
Wayne	Owen	US Forest Service
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3. Technical Supplement

This technical supplement provides additional information on the five-tiered approach used to identify the climate change-related challenges, needs, and opportunities associated with managing ecosystems, habitats, species, and resources in the NPLCC region in light of current and projected climate change effects. We used the principles and methods of applied policy research and the grounded theory approach to qualitative data analysis (Box 7, p. 189) to investigate three research questions:

1. What are the challenges, needs, and opportunities for experts and stakeholders working at the nexus of climate change impacts, adaptation, and ecosystem response to manage marine, freshwater, and terrestrial ecosystems, habitats, and species in light of current and potential future climate change impacts in the NPLCC region? Experts and stakeholders include sustainable resource managers, conservation practitioners, and scientists
2. What is the decision-relevance, spatial scale, temporal scale, timeline, and sense of urgency for the challenges, needs, and opportunities identified in Research Question #1?
3. Which partners and ongoing efforts are currently available to assist with addressing the challenges, needs, and opportunities identified in Research Question #1?

Consistent with the principles and methods of applied policy research and the grounded theory approach to qualitative data analysis, a combination of surveys, semi-structured interviews, web-based focus groups, and in-person workshops are used to investigate these three questions. In each of these venues, project participants identified climate-related science, management and traditional ecological knowledge needs, key characteristics of those needs, the tools and other support to meet those needs, and opportunities related to advancing landscape-scale conservation and resource management in light of climate change.

Tier 1: Identify sample population

Project participants were identified using a purposive, network sampling method. *Purposive* sampling is appropriate when the investigators would like to target a specific population likely to provide data that are detailed and relevant for the research question; it is often used in exploratory research (Neuman, 2004, p. 138-140; Jupp, 2006, p. 244-45). In this case, the specific population is staff from federal, state, and tribal agencies, conservation and climate change NGOs, and university scientists tackling climate change in their ecosystem, habitat, and species-related work in the NPLCC region. *Network* sampling is a multistage purposive technique used to identify and sample the people in a network, where "each person or unit is connected with another through a direct or indirect linkage" (Neuman, 2004, p. 140). Sampling "begins with one or a few people or cases and spreads out on the basis of links to the initial cases" until "no new names are given, indicating a closed network, or because the network is so large that it is at the limit of what [the researcher] can study" (Neuman, 2004, p. 140). In this case, the linkage is those tackling climate change in their ecosystem, habitat, and species-related work in the NPLCC region and we continued to sample until few new names were added to the sample. The principal advantage of purposive and network sampling is the ability to identify specific populations that may be difficult to identify or reach and are also likely to provide relevant information, while the principal disadvantage is that the sampling "rests on the subjectivity of the researcher‟s decision making," which is a source of potential bias and may impair the validity of research findings (Jupp, 2006, p. 245). However, "these effects may be reduced by trying to ensure that there is an internal consistency between the aims and epistemological basis of the research, and the criteria used for selecting the purposive sample" (Jupp, 2006, p. 245). Please see the Methodology for more information on the former; the latter is addressed here as well as in the Methodology.

To generate the list of 396 prospective project participants, we first queried our NPLCC contacts database for those who had been previously contacted to participate in projects focusing on the NPLCC region by National Wildlife Federation, the U.S. Fish and Wildlife Service, or the NPLCC. We also queried our NPLCC contacts database for those who have specific expertise in climate change and ecosystem, habitat, and/or species response. The initial list was distributed to the NPLCC S-TEK Subcommittee, NPLCC Steering Committee, and well-networked individuals in the region via email with a request to suggest additional participants and further distribute among their networks to identify additional participants. Where gaps remained in representation of ecosystems, habitats, or species, we conducted interviews with several individuals to identify additional prospective project participants. We also reviewed staff profiles at federal and state agencies, universities, conservation and climate change NGOs, and tribally-affiliated organizations to identify participants and fill gaps in representation of location or expertise (see footnote

Box 7. Applied Policy Research and the Grounded Theory Approach to Qualitative Data Analysis

Applied policy research is characterized by methods designed to meet pre-determined objectives shaped by specific information requirements in a decision making process. Research is typically conducted in teams over shorter timelines (months rather than years), involves the generation of new data using interviews, group discussions, or observational work, and emphasizes transparency and making data available in a form that is useful and relevant for decision makers. These methods respond to the short-term deadlines and need for transparency associated with informing key activities or decision points in a decision making process.

The *grounded theory approach to qualitative data analysis* is a specific methodology for "building theory from data" (Corbin and Strauss 2008, p. 1). Data are collected through surveys, interviews, and other methods. Surveys are well-suited to answering research questions such as ours, which ask "who, what, where, how many, and how much." Three stages of coding allow themes held within data to emerge in a meaningful way:

- *Open coding* identifies concepts that seem important given the context of the interview or survey. Initial concepts often proliferate and are organized into categories. "Capacity" is an example of a category that encompasses open codes related to training, funding, time, and personal knowledge.
- *Axial coding* relates categories according to their structure and process, thereby identifying major research themes. Structure describes the "why" and process describes the "how" of the relationships among categories. Table # in Appendix # provides an example of open and axial coding.
- *Selective coding* identifies specific cases that effectively illustrate the themes identified through axial coding, thereby providing supporting evidence for research findings. In this report, these are the survey responses, excerpts from web-based focus group transcripts, and worksheet comments used to illustrate themes and concepts.

Sources: Corbin & Strauss (2008). Neuman (2004). Ritchie and Spencer (2002).Strauss & Corbin (1998). Yin (2003).

for example list).[111] Through this process, we targeted the sample population of interest and the number of new names we received diminished over time, indicating the purposive and network sampling methods generated a list of prospective project participants that met our criteria: staff from federal, state, and tribal agencies, conservation and climate change NGOs, and university scientists addressing climate change in their ecosystem, habitat, and species-related work in the NPLCC region.

In all communications, we encouraged prospective project participants to distribute invitations widely among interested colleagues. To keep track of the number of prospective project participants reached by these methods, we also requested they copy us on all their communications. However, it is possible we were not copied on all communications, so the number of project invitees may exceed 396 individuals.

Of the 396 prospective project participants, 195 participated in the survey, web-based focus groups, and/or in-person workshops (response rate: 49%). Sixteen people reviewed the draft report, four of whom participated in the project for the first time. The 195 people who participated in the project are well-distributed across the NPLCC region (response rate: 49%; see Table 2, p. 8), with most participants employed with U.S. federal agencies (Table 3, p. 9). Forty percent (40%) of land in the U.S. portion of the NPLCC region is under the jurisdiction of U.S. federal agencies (US FWS 2010b); our sample reflects this distribution.

Project participants represent a broad range of work responsibilities and activities, including natural and sustainable resource management, conservation, climate change adaptation, review and enforcement of regulations, permitting, research, and capacity-building. Our sampling method and survey questions did not ask potential participants to identify their area(s) of ecosystem expertise, but the distribution of participants in the web-based focus groups and in-person workshops indicates marine- and coastal-focused topics were strongly represented in comparison to freshwater-, multi-ecosystem, and terrestrial-focused topics. A focus on freshwater, terrestrial, and multi-ecosystem topics would be appropriate for future research.

Tier 2: Distribute survey and analyze responses

In December 2011, January 2012, and May 2012, web-based surveys were distributed to ~300 land and resource managers, scientists, and conservation practitioners working in federal, state, provincial, and tribal agencies, NGOs, and universities in the NPLCC region. Seventy-nine responses were received (response rate: ~25%). The survey was comprised of ten open-ended questions that asked respondents to briefly describe their work, how climate change affects their work, the challenges presented by climate change, and any current or future opportunities to address climate change in their work. See Appendix 4 (p. 197) for a copy of the survey instrument. Six concepts and themes related to climate-related management challenges emerged from the qualitative data analysis of survey results using the grounded

[111] Staff profiles were reviewed at many organizations including the Oregon Climate Change Research Institute, University of Washington Climate Impacts Group, Pacific Northwest and Pacific Southwest Research Stations of the U.S. Forest Service, USGS Water Science Centers, USGS Western Ecological Research Center, Canada Department of Fisheries and Oceans, Parks Canada, British Columbia Ministries of Environment and Forests, Lands, and Natural Resource Operations, fish, wildlife, game, natural resource, parks, and ecology agencies in Alaska, Washington, Oregon, and California, Alaska Coastal Rainforest Center, EcoAdapt, Conservation Northwest, The Nature Conservancy, Geos Institute, Conservation Biology Institute, Stillwater Sciences, ESSA, West Coast Aquatic Management Board, World Wildlife Fund – Canada, Columbia River Intertribal Fish Commission, Northwest Indian Fisheries Commission, Central Council Haida and Tlingit Tribes of Alaska, and Coastal First Nations.

theory approach. A similar series of nine concepts and themes representing climate-related management opportunities were also identified from the qualitative data analysis of survey results using the grounded theory approach (Table 5, p. 13).

Tier 3: Convene web-based focus groups conduct semi-structured interviews, and analyze input

In December and January 2012, we worked closely with the University of Washington Climate Impacts Group (CIG) to build on the concepts and themes isolated through the qualitative analysis of survey results and formulate a series of more specific questions to ask during the web-based focus groups. These questions were designed to inform NPLCC S-TEK decision making by more clearly articulating the themes and concepts described in the survey and acquiring additional information on the decision-relevance of the challenges and opportunities identified by survey respondents. The primary questions asked of all groups were (see Appendix 5, p. 199 for a longer list of sample questions):

- What are the key challenges you face in your work due to current and projected effects of climate change?
- If you are a manager, what do scientists ask you for? If you are a scientist, what do managers ask you for?
- What are the key science or data gaps to fill to better address climate change in your work?
- What are the 2-3 key products or roles that you would like to see the NPLCC provide or fulfill?

In January, February, and May 2012, 107 individuals participated in one or more of thirteen web-based focus groups designed to better articulate and understand climate change-related management challenges and opportunities (response rate: ~29%). Participants selected the focus group(s) in which they participated based on their expertise and interest in marine, coastal, freshwater, and/or terrestrial ecosystems, habitats, and species, as well as the biogeophysical focus of the focus group (Table 6, p. 14). All focus groups began with an overview of the scientific literature on climate change effects and adaptation approaches particular to the biogeophysical region discussed in the focus group, then proceeded to a semi-structured discussion of challenges, opportunities, and needs. Each focus group was 2 to 2.5 hours long. The first ten focus groups were held in January and February 2012. These targeted marine/coastal (5 focus groups; 79 participants) and freshwater (5 focus groups; 29 participants) ecosystems, habitats, and species. In March 2012, the NPLCC awarded additional funds to work on the region‟s terrestrial ecosystems. Semi-structured interviews with terrestrial experts to identify and discuss potential concepts, themes, and needs for terrestrial ecosystems were conducted in March and April 2012. The final three focus groups were held in May 2012 and targeted terrestrial ecosystems, habitats, and species (31 participants). Although our funding limited the number of terrestrial focus groups to three instead of five, the number of participants across the focus groups indicates comparable representation of freshwater- and terrestrial-focused participants and strong representation of marine- and coastal-focused participants (Table 6). To account for the fact that three web-based focus groups were convened for terrestrial systems instead of the five that were convened for marine/coastal and freshwater systems, a weighting factor of 1.67 was applied to each instance in which a terrestrial focus group was cited for a need or activity area. This normalizes results across focus groups (see Tier 5 for more information).

Results from the survey and web-based focus groups were transcribed and analyzed using the grounded theory approach to qualitative data analysis. Table 9 (p. 195) is an example of the analytical process employed. Results were also compared with the analysis of survey responses to identify potential science and traditional ecological knowledge needs. Several categories of potential information needs emerged from the data as being representative of the broad range of needs identified by project participants (Table 5, p. 13). These categories of information needs were further grouped into science-based and science-support potential information needs, then discussed during the Tier 4 in-person workshops. To promote transparency in data generation and assessment, transcripts are available to all project participants. Preliminary findings from the first ten web-based focus groups (and first in-person workshop) were also compiled by NWF in February 2012 and sent for review by project participants. Reviewer comments were incorporated into the final version of the preliminary findings.

Tier 4: Convene in-person workshops, conduct semi-structured interviews, and analyze input

Three day-long in-person workshops were held in Portland, Oregon (Feb. 28, 2012), Juneau, Alaska (April 20, 2012), and Arcata, California (June 11, 2012). Representing a wide range of sectors and expertise, thirty-nine participants attended the Portland workshop, forty-three participants attended the Juneau workshop, and twenty-nine participants attended the Arcata workshop (Table 7, p. 15). NPLCC staff were present to listen and learn from participants. With additional funding from the NPLCC in March 2012 to work in the region‟s terrestrial ecosystems, we conducted semi-structured interviews with terrestrial ecosystem experts to identify potential terrestrial ecosystem topics for the Juneau and Arcata workshops and associated web-based focus groups described in the section on Tier 3.

The three in-person workshops build on Tiers 2 and 3 by asking participants to use the lists generated by survey and web-based focus group participants to identify NPLCC-wide needs that, if fulfilled, would advance efforts to address climate change in their work (Table 8, p. 16). Workshop participants worked in self-selected break-out groups to identify these needs. Prior to discussions of potential science-based needs, participants were asked to narrow a list of 9-15 potential topics identified through Tiers 2 and 3 to come up with 6-7 topics to discuss in greater detail. Participants were then asked to evaluate that need across four criteria, each of which addresses Research Question 2 or 3 by providing information to the NPLCC about when, where, or for what purpose a particular need is suggested:

- Decision-relevance: what decisions this information would help answer
- Spatial and temporal scale: specify the relevant geographic region and whether the information is needed on an annual, seasonal, daily, etc. timescale
- Timeline/urgency: when this information is needed, tell us why this is important
- Partners/ongoing efforts: who might already have this information or might be well suited to develop it

To provide a transparent record of events, workshop proceedings from the Juneau and Arcata workshops were compiled and sent for review by workshop participants. As mentioned in discussion of Tier 2, proceedings from the Portland workshop were also combined with preliminary findings from the first ten web-based focus groups, then sent for review by workshop and focus group participants.

Multi-ecosystem topics were discussed in each workshop, most noticeably in the Arcata and Juneau workshops: the choice of topics indicates a focus on terrestrial topics in the Arcata workshop, particularly the intersection of terrestrial systems with hydrology and freshwater systems. In the Juneau workshop, similar emphases on aquatic, terrestrial, and multi-ecosystem topics are observed (Table 8, p. 16).

Tier 5: Analyze and synthesize all input to produce report

In the fifth and final tier, we analyzed and synthesized approximately 350 pages of survey responses, web-based focus group input, and workshop discussions using the grounded theory approach to qualitative data analysis to produce a draft report. More specifically, after each focus group or workshop, the authors and their partners reflected on the discussion to articulate new insights and identify topics to investigate further in subsequent meetings. This iterative process identified new concepts to explore and provided new meaning for previously identified concepts, challenges, needs, and opportunities.

In addition to the qualitative analysis of survey responses, formal qualitative analysis of focus group and workshop input occurred at two points: after the completion of the aquatic focus groups and Portland workshop (Tillmann & Siemann 2012), and again after all focus groups and workshops were complete. Approximately forty initial concepts and themes were identified. These describe the array of tools, information, and related assistance project participants documented as needs. Examples are provided in Table 5, p. 13 and Table 9, p. 195; the latter is an example of the analysis utilized. Through the iterative process of discussion and qualitative data analysis, the approximately forty initial concepts and themes were synthesized and partitioned into four discrete needs: (1) decision-support systems and tools, (2) collaboration and other capacity-building activities, (3) new or different science, data and information, and (4) science communication and outreach. These constitute the major findings of this research (see Chapter III, p. 18 for more information). In addition, seventeen activity areas specific to ecosystems, habitats, species, or resources were identified (Chapters IV-IX).

After identifying the needs and activity areas, an analysis of the frequency with which a need or activity area was cited across venues and the repetition with which a need or activity area was cited within venues was conducted. The frequency analysis identified which needs and activity areas are cited in more than 50% of "venues" available to project participants – these are the survey, thirteen web-based focus groups, and three in-person workshops (Figure 2, p. 17 and Table 1, p. xv). To account for the fact that three web-based focus groups were convened for terrestrial systems instead of the five that were convened for marine/coastal and freshwater systems, a weighting factor of 5/3, or 1.67, was applied to each instance in which a terrestrial focus group was cited for a need or activity area.[112] This normalizes results across focus groups. The repetition analysis identified which needs and activity areas were discussed consistently by many participants within many venues. The qualitative data analysis and ensuing frequency and repetition analyses provide a starting point for further analysis and identification of potential climate change-related science and traditional ecological knowledge needs and opportunities in the NPLCC region.

[112] Mathematically, $3x=5$, where $x=5/3=1.67$ is the weighting factor to normalize the three terrestrial ecosystem focus groups with the five focus groups each for marine and freshwater ecosystems. Therefore, for each citation of a terrestrial focus group, 1 terrestrial citation*1.67 weighting = 1.67 weighted citations.

A preliminary version of the draft report was released to the NPLCC S-TEK Subcommittee on August 3, 2012 for an informal review and to inform committee activities. The completed draft report was released to all project invitees and participants, as well as the NPLCC S-TEK Subcommittee, for an initial 2-week review on August 25, 2012. Prior to the report release, an email was sent to all potential reviewers to notify them of the upcoming review period. On September 5, 2012, NWF held a WebEx and conference call to discuss the report and receive verbal feedback from reviewers. The review period was extended to September 18, 2012 in order to receive additional comments. From August to December 2012, fifteen pages of email comments and approximately 260 in-text comments from the sixteen people who reviewed the draft report were incorporated to produce this final report.

Discussion

The results of the exploratory research suggest there are four core, cross-ecosystem needs related to landscape-scale climate change adaptation, conservation, and sustainable resource management in the NPLCC region (Chapter III, Figure 2 on p. 17, and Table 1 on p. xv). In addition, these results provide a "first look" at the climate change-related challenges, needs, and opportunities in the NPLCC region particular to ecosystems, habitats, species, and resources (Chapters IV-IX). Several of these activity areas are cross-ecosystems activity areas (Figure 2 on p. 17, and Table 1 on p. xv).

This study engaged a broad range of conservation, climate change, and resource management professionals working at the nexus of climate change and conservation in the NPLCC region, but as the first assessment of its kind, this synthesis should not be considered completely comprehensive. It is most representative of the 195 people who participated in the project. Results are well-distributed by location and strongly representative of marine- and coastal-focused topics. In addition, multi-ecosystem topics were discussed in many of the venues even if the venue(s) were targeted toward a particular system. This occurs most noticeably in the Arcata and Juneau workshops: the choice of topics indicates a focus on terrestrial topics in the Arcata workshop, particularly the intersection of terrestrial systems with hydrology and freshwater systems. In the Juneau workshop, similar emphases on aquatic, terrestrial, and multi-ecosystem topics are observed (Table 8, p. 16).

Two assessments similar to this one have been conducted for marine and coastal ecosystems (NOAA 2011, Finzi Hart 2012). These needs assessments identified many of the challenges, needs, and opportunities included in this report and are a source of external support for the findings reported herein. We encourage repeating and building from these efforts to augment and revise our findings as appropriate, with specific attention to freshwater, terrestrial, and multi-ecosystem topics. Please see Appendix 1 (p. 175) for a list of project participants.

Table 9. An example of open and axial coding, beginning with open coding on the left and proceeding to the final list of axial codes on the right			
Initial Open Coding[1] These capture both challenges and needs.	**Initial Axial Coding** Relating open codes by properties and dimensions, structure and process	**Product of Iterative Open and Axial Coding[2]** Open and axial codes sometimes emerge as descriptions of a new axial code or as selective codes illustrating an axial code.	**Final List of Axial Codes** The relationship between the open codes and initial axial codes is evident.

CAPACITY
• Subcategories: Training, Funding, Time, Personal Knowledge
• Properties & Dimensions (examples):
  ○ **amount** of capacity (ranging along *dimension of lacking to sufficient*)
  ○ **availability** of capacity (ranging along *dimension of unavailable to available*)
  ○ **acquisition** of capacity (ranging along *dimension of difficult to easy to acquire*)
  ○ **coordination** of capacity (ranging along *dimension of uncoordinated to coordinated*)
  ○ **action** on capacity (ranging along *dimension of none to build*).
 	
COLLABORATION
• Subcategories: People, Projects, Institutions, Funding
• Properties & Dimensions (examples):
  ○ **amount** (ranging along *dimension of little to extensive)*
  ○ **frequency** (ranging along *dimension of rare to frequently)*
  ○ **ease** (ranging along *dimension of easy to difficult)*
  ○ **action** (ranging along *dimension of decrease to increase)*
 	
SCIENCE AND INFORMATION
• Subcategories: Research, Data, Scenarios, Vulnerability assessment, Case studies
• Properties & Dimensions (examples):
  ○ **amount** (ranging along *dimension of less to more*)
  ○ **type** (ranging along *dimensions of*
	Axial Code: Collaboration and other capacity-building activities
	
	Explanation: The open code of collaboration (specifically dimension of increasing collaboration) was so often described in relation to the open code of capacity (specifically dimension of building capacity) that these two open codes were joined in the axial code of "collaboration and other capacity-building activities."
	
	Axial Code: Synthesis products
	
	Explanation: Analysis of the open codes science and information, climate clearinghouse, and tools suggested a pattern along the property of **synthesis** with dimension "*synthesized*." Recognizing the pattern suggested an axial code "synthesis products."
		Example 1: Project participants often described the open codes of guidance, tangible examples of progress or success, actionable information and solutions, and the axial code of synthesis products as useful for improving their ability to address climate change, either by providing various forms of training (the first three) or by making sense of the proliferation of data and information related to climate change for particular scales or regions (synthesis products). These open codes and the axial code, "synthesis products," are related to capacity chiefly through the dimensions of building, more, available, and coordinated and are therefore grouped in the axial code "collaboration and other capacity-building activities." Thus, open and axial codes sometimes emerge as descriptions of a new axial code or as selective codes illustrating an axial code.
		
		Example 2: Overarching axial codes are those of "challenges" and "needs." The challenges and needs are often related along properties and dimensions having to do with amount (lacking vs. sufficient) such that the response to a "lack of" is a stated need to provide more of what is lacking. For example, a "lack of capacity" is associated with the need for "capacity-building activities." Thus, in the final list of axial codes, the relationship among the open codes and initial axial codes is evident.
			CHALLENGES
			• Difficult to identify, understand, and use climate change science, data, tools, and/or information
			• Insufficient capacity inhibits addressing climate change
			• Political, cultural, social, and institutional barriers inhibit efforts to address climate change
			• Lack of coordination, collaboration, and communication among people, projects, institutions, and funding
			• Difficult to incorporate or address uncertainty
			• Climate-related priorities compete with other priorities and climate change has not been mainstreamed sufficiently into current environmental priorities
			
			NEEDS
			• Decision-support systems and tools
			• Collaboration and other capacity-building activities
			• New or different science, data, and information
			• Science communication and outreach

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<td>different to same, basic to applied)

scale (ranging from global to downscaled)
degree of visualization (ranging from image-heavy to written)

CLIMATE CLEARINGHOUSE

<u>Subcategories:</u> Brain trust, Librarian, Yenta service
<u>Properties & Dimensions (examples):</u>

amount (ranging along dimension of less to more)
type (ranging along dimensions of general to targeted)
content (ranging from simple to complex, basic to thorough)

TOOLS

<u>Subcategories:</u> Visualization models, maps, vulnerability assessments, decision-support tools
<u>Properties & Dimensions (examples):</u>

amount (ranging along dimension of less to more)
scale (ranging from regional to local)
degree of dynamism (ranging from static to dynamic)
degree of visualization (ranging from image-heavy to written)
audience (ranging from general to targeted)

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1. Other open codes include coordination, communication, leveraging, management and policy, institutional barriers, political barriers, cultural barriers, social barriers, guidance, tangible examples of progress or success, action, creativity, uncertainty, enforcement, benefit-cost analyses, cost estimates, estimates of tradeoffs, visuals (mapping, before and after images, websites)
2. The iterative process of open and axial coding can suggest dropping some themes, examining other themes in more depth, or identify new themes. In this way, the many open codes identified early-on are refined until they reflect and capture the input provided and context described by project participants. Refinement occurred throughout the project as the ideas proposed in the survey and articulated by the authors were tested, augmented, or dropped during the web-based focus groups and in-person workshops. New ideas, concepts, and themes were also introduced in the web-based focus groups and in-person workshops. These received the same iterative analysis by the authors and participants until six challenges and four core needs emerged from the analyses as representative of participants‟ input and the context they described.
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4. Survey Instrument

Thank you for taking the pre-focus group survey. The purpose of this survey is to acquire information about the work you do, how climate change affects your work, and the ways in which you have or would like to address climate change impacts in your work. Survey responses will be used as a springboard to focus group discussions, and will provide the necessary context for discussing challenges and information needs associated with addressing climate change impacts in your work.

All survey responses will remain confidential. The survey should take approximately ten minutes to complete and includes nine questions. Questions 1-3 will ask about your work duties, as well as how climate change may affect your current and future work.

1. In your work, what are your primary responsibilities and activities? This may include natural resource management, conservation, regulatory, permitting, and other obligations.

2. How does climate change affect the responsibilities and activities you described in Question 1? This may include current and potential future effects.

3. In your work, what opportunities do you see to integrate climate change into decision making? This may include natural resource management, conservation, regulatory, permitting, and other decisions.

Questions 4-6 ask about the challenges, available tools, and information needs associated with fulfilling your management, conservation, regulatory, permitting, and other obligations in light of climate change impacts.

4. What challenges do you currently face in incorporating climate change science into the responsibilities and activities you identified in Question 1?

5. What information, tools, research, or other items do you currently use to address the challenges you described in Question 4? Please be as specific as possible.

6. What additional information, tools, research, or other items would help you overcome the challenges you identified in Question 4?

Questions 7-10 will ask for key demographic information and will describe an opportunity to comment on two draft reports on climate change impacts and adaptation approaches in your region.[113]

7. Which focus group(s) will you be participating in? Please select all that apply. (required)

8. Please consider providing your first and last name, as it would be very useful for our internal planning. All survey responses will remain confidential. Thank you.

[113] In March 2012, NWF was awarded additional funds from the NPLCC to replicate our existing work in marine and freshwater ecosystems for the region‟s terrestrial ecosystems. As a result, Questions 9 and 10 shown here were replaced with a single question (#9): "If you have any comments or suggestions, please enter them below. Thank you for taking this survey. Your responses will provide a valuable foundation for the focus group discussions."

9. This question asks for any feedback you may have on two Draft Final Reports recently completed by National Wildlife Federation. These focus groups build off of the reports. The reports compile the published scientific and grey literature on climate change effects and adaptation approaches for marine/coastal and freshwater/riparian ecosystems in the North Pacific Landscape Conservation Cooperative Region. If you have not received the reports via email, they can be accessed at www.nwf.org/climate-smart in the "Adaptation Reports" section.

In the comment box below, please describe any corrections or additions you would like to see in the Draft Final Reports. Please provide references that can be cited for the new information. If you need more space, have documents to share, or would like to answer this question another time, email Patricia Tillmann at tillmannp@nwf.org.

Note: For those participating in the BC Coast Marine group, WWF-Canada and the Canadian Parks and Wilderness Society will release a similar report for the BC Coast in January 2012.

10. If you have any additional comments or suggestions, please enter them below. Thank you for taking this survey. Your responses will provide a valuable foundation for the focus group discussions. Please look for an email with the date and time of your focus group, agenda, and other materials in one to three weeks. If you received a link to a scheduling poll in your email invitation and have not yet taken the poll, please do so. Thank you.

5. Examples of Web-based Focus Group Discussion Questions

Web-based focus group discussion questions are divided into the six categories identified from the survey responses.

1. **Identifying and using science, data, tools, and/or information**
    - What climate-related information do you (or would you) use in your work?
    - Are your decisions hindered by a lack of climate-related information? If so, what is an example?
        1. Is the example similar to other challenges you have faced? In what way(s)? How did you address the other challenge? Would a similar approach work for climate change?
    - What are three tools that would really help you address climate change?
        1. What would the tools be used for? What challenges would they address? What decisions could you make?
    - Downscaled or fine-scale data is a commonly stated need. Recognizing that finer scale does not mean more certainty, what scale would you ideally like to have? What scale can you live with?
    - Decision-support tools for climate change are a commonly stated need. What type of tool would be most helpful for you?
        1. Is visualization (e.g. maps of current and future impacts) a high priority?
    - Assistance with incorporating climate change into existing work is a commonly stated need. What specific assistance are you looking for (e.g., scenario selection, selecting & prioritizing adaptation options, incorporating uncertainty, vulnerability assessment, etc.)?
2. **Capacity (people, financial, technical, political, institutional)**
    - If your organization had the information needed to address climate change, would your organization have the capacity to use the information?
        1. If not, what capacity would you need?
    - How have you addressed capacity issues in other contexts? Could you use a similar approach to address climate change?
        1. What approaches have others on the call used to address capacity issues?
3. **Institutional, political, cultural, and/or social factors**
    - Many of you described opportunities to incorporate climate change into existing policies, planning processes, and similar endeavors.
        1. How are you thinking about doing this within your existing institutional and political climate?
        2. What challenges are you facing (political, financial, technical, etc.)?
4. **Addressing uncertainty**
    - What are the key sources of uncertainty in your climate change work?
    - Scenarios are a commonly cited method to address uncertainty.
        1. Would scenarios be a helpful tool to address uncertainty in your work? If so, what type of scenario(s) would be helpful and why?
        2. What timeframes do you need scenarios for? When do you need them by?

    3. Do you already use scenarios in your work?
        1. If not, does your organization have trained staff to conduct this type of work?

5. **Coordination, collaboration, and communication**
    - Who do you need to communicate and coordinate with and why?
    - What are you specifically trying to communicate and coordinate more effectively?
    - What currently inhibits better communication and coordination?
    - What is (are) the best mechanism(s) for improving communication and coordination?
    - Are there adequate opportunities for learning from peers working in similar ecosystems located in different jurisdictions or organizations?
        1. If yes, are you able to take advantage of these opportunities? If no, what could be done to facilitate this? A "climate clearinghouse" or "Wiki" has been suggested – would this be a helpful way to connect with peers?
        2. What do you (or would you) like to ask your peers? How would this help you address climate change and make the decisions you are required to make?

6. **What are the key questions and priorities?**
    - What are the most important questions about climate change impacts or adaptation that you or your organization need answered in order to effectively address current and projected changes?
    - What are the key support items the NPLCC could provide to make your work easier and more effective in addressing climate change?
    - Testing adaptation strategies/actions was a commonly cited need. Which strategies/actions would you like to see tested first and why?
        1. Examples: conducting vulnerability assessments, modifying existing restoration, conservation, or sustainable resource management, identifying novel indicators, etc.