NPLCC STRATEGY FOR SCIENCE AND TRADITIONAL ECOLOGICAL KNOWLEDGE, 2013—2016 (Version 1.0)

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EXECUTIVE SUMMARY

Climate change poses numerous challenges to natural resource managers and conservation professionals. The North Pacific Landscape Conservation Cooperative (NPLCC) is one of 22 cooperatives in North America established to respond to these challenges through collaboration among scientists, managers, and decision-makers from diverse organizations. The NPLCC seeks to maximize the ability of partners, constituents, and stakeholders to make informed conservation and sustainable resource management decisions under a changing climate, within a region extending from southcentral Alaska to northwestern California. This strategy will guide NPLCC activities from 2013 to 2016 and help identify opportunities for collaboration with U.S. and Canadian partners, uniquely emphasizing the combination of western science and the Traditional Ecological Knowledge (TEK) of Tribes and First Nations.

The NPLCC's Science and Traditional Ecological Knowledge Subcommittee (S-TEK) developed this strategy with guidance and oversight from the program's governing body, the Steering Committee. The S-TEK benefited from the results of a Steering Committee Framing Workshop to identify natural resource information and support needs, and the findings of a National Wildlife Federation project involving more than 200 scientists and resource professionals from throughout the region.

This S-TEK Strategy identifies equally important *Guiding Principles* and *Priority Topics.* The Principles provide guidance for the types of activities the NPLCC will support, and the Topics describe issues for which those activities will be of particular benefit to conservation and sustainable resource management within the NPLCC in the face of climate and related stressors. Hundreds of potential areas of focus were identified, screened and evaluated to yield the *Priority Topics* shown below. Several distinct kinds of actions can be applied to any of the five Topics, ranging from collaboration and information sharing workshops to collection and synthesis of new scientific data. Annual planning will determine what types of actions to implement consistent with both the Strategy's *Guiding Principles* and *Priority Topics*.

Guiding Principles	*Priority Topics*
In annual implementation planning, and in the activities it supports, the NPLCC will: • **Focus on helping managers understand the availability and effectiveness of adaptation and mitigation response actions** • **Focus on facilitating coordination, collaboration, and capacity building, and on developing or assisting with tools to assist decision-makers** • **Identify and promote opportunities to use TEK to inform partner and stakeholder decisions** • **Promote and facilitate consideration of the connections and interactions between ecosystems**	• **Effects of hydrologic regime shifts on rivers, streams, and riparian corridors** • **Effects of change in air temperature and precipitation on Forests** • **Effects of changes in sea levels and storms on marine shorelines, the nearshore and estuaries** • **Effects of the changes in the hydrologic regime on anadromous fish** • **Invasive species, diseases, pests and their effects on biological communities**

I. INTRODUCTION

The effects of climate change on the Earth's physical and ecological processes pose unprecedented risks to individual species and entire biological communities, many of which humans depend on for life support and well-being. In responding to these challenges, new kinds of reliable, predictive information at multiple scales will be needed to support informed and effective landscape level conservation and sustainable resource management decisions. New scientific findings to inform planning (such as data, models, and forecasts), support for implementation (such as new tools and approaches) along with increased coordination, collaboration and capacity building will be required. These needs are unlikely to be fulfilled by organizations working within traditionally defined boundaries.

Landscape Conservation Cooperatives (LCCs) are an international response to the need for better informed natural resource adaptation and mitigation in the face of climate change and other environmental stressors. A network of 22 LCCs provide a forum for U.S., Canadian, and Mexican States, Provinces, Territories, and Federal agencies; Tribes and First Nations; universities; non-governmental organizations and other conservation partnerships and entities to work together across their boundaries in a new way. A hallmark of LCCs is robust collaboration among scientists, managers, and decision-makers from the partner organizations, seeking to jointly support effective natural resource management actions on North American landscapes.

LCCs were delineated using biogeographic attributes rather than traditional organizational boundaries. The North Pacific LCC (NPLCC) encompasses approximately 204,000 mi^2 (530,000 km^2) extending from southcentral Alaska to northwestern California, including parts of four western U.S. states, one Canadian province and one Canadian territory (Figure 1).

Figure 1: NPLCC Boundaries

The coastal temperate rainforests within this unique ecoregion are among the last remaining intact temperate rainforests of their kind in the world. The entire landscape is characterized by interconnected marine, freshwater, and terrestrial ecosystems, further linked by key species assemblages such as Pacific salmon and migratory birds. Strong human cultures (including numerous Tribes and First Nations) have thrived on the region's abundant resources since the last ice age, developing a rich body of Traditional Ecological Knowledge (TEK). With public lands making up approximately 78 percent of the NPLCC, effective resource management and collaboration of governmental entities is particularly important.

This *NPLCC Strategy for Science and Traditional Ecological Knowledge* (S-TEK Strategy, or "Strategy") is a key element of the NPLCC's planning. It was developed by the NPLCC's Science and Traditional Ecological Knowledge Subcommittee (S-TEK), which was established by NPLCC Steering Committee in their Charter (http://www.fws.gov/pacific/Climatechange/nplcc/framework.html). The 22 North American LCCs encompass diverse landscapes and are self-guided by their steering committees, and thus the issues and activities differ among programs. This S-TEK strategy uniquely emphasizes the combination of western science and the Traditional Ecological Knowledge of Tribes and First Nations to support natural resource stewardship.

II. PURPOSE AND OBJECTIVES OF THIS STRATEGY

This four-year S-TEK Strategy provides overall direction and guidance for activities related to landscape-level conservation and sustainable resource management for the NPLCC. It does not identify specific project-level actions; rather it defines some *Guiding Principles*, a set of high *Priority Topics*, and corresponding types of actions, in a flexible framework to support more specific annual planning. Annual planning by the NPLCC will define project-level actions within the Strategy's framework, and will specify NPLCC actions on an annual basis.

The S-TEK Strategy will be incorporated into the 10-year NPLCC Strategy along with related strategies for communication, outreach, and partner engagement, which are all currently being developed. Through the annual planning process, these strategies will guide NPLCC project development, funding, and dissemination of results. The strategies are also envisioned to support a broader purpose: to support related actions by the natural resource and conservation community at large, consistent with their own mission and goals. The S-TEK Strategy, created by partners committed to working together on issues that supersede organizational boundaries, can point to areas where collaboration and leveraging of resources that are particularly valuable to the entire community. The LCC itself can be a vehicle for leveraging resources among organizations to fulfill common needs, and for stimulating collaboration, ranging from planning to on-the-ground implementation. For the unique and treasured landscapes it addresses, this Strategy is intended to support a wide range of these needs for information development and application, in support of conservation and sustainable natural resource management in a societal decision context.

The emphasis of this Strategy is on principles, topics, and actions that will be most useful for management decisions of partner entities. A focus was placed on opportunities for the NPLCC to fill critical gaps not likely to be addressed by individual partners working alone. While selecting Guiding Principles and Priority Topics the S-TEK aimed for a balance across stakeholder interests and the NPLCC geography.

This Strategy also recognizes the importance of considering both western science and TEK. Seven projects were funded by the NPLCC in 2012 that focus on gaining a better understanding of how and

where TEK can be incorporated into the work of the NPLCC http:/www.fws.gov/pacific/Climatechange/nplcc/products.html). Results from these projects along with direction from the NPLCC Tribal/First Nations Committee, which is still in development, will be incorporated in this Strategy when they are available. Section VI describes the process by which the Strategy can be updated.

S-TEK Strategy Objectives

Strategy development began with NPLCC's mission and goals identified by the Steering Committee (http://www.fws.gov/pacific/Climatechange/nplcc/framework.html). The S-TEK Strategy seeks to *maximize the ability of partners, constituents, and stakeholders to make informed conservation and sustainable resource management decisions under a changing climate*. This objective directly addresses Goal 1 of the NPLCC (*Maximize the ability of partners to make informed decisions with respect to conservation and sustainable resource management of priority natural and cultural resources subject to climate change and related large-scale stressors in the NPLCC region*). Achieving this goal will require development of the right information (data, TEK, information syntheses, models, and tools) at the right scale (tailored to the particular diverse issues on the landscape) with actions applied at the right time to be effective. Ensuring that this information can be used is equally important; activities to provide tools, perspectives, and support for using information effectively in decision-making might be the pressing need for some topics.

Additional detailed S-TEK Strategy objectives are listed in the sidebar, and collectively they address NPLCC goals #1, #2, #3, #4, #5, and #6.

Strategy Objectives

The primary objective of the S-TEK strategy is to support the goals of the NPLCC, and in particular to address Goal #1: Maximize the ability of partners to make informed decisions with respect to conservation and sustainable resource management of priority natural and cultural resources subject to climate change and related large-scale stressors in the NPLCC region.

To support this primary goal of the NPLCC, six Strategy-specific objectives were defined:

- Maximize the ability to partners, constituents, and stakeholders to make informed conservation and sustainable resource management decisions
- Identify science and TEK information, tools, perspectives, and resources needed to support decisions throughout the region
- Determine what information and support gaps are most appropriately addressed by the NPLCC
- Deliver data, information and knowledge so they can be used most effectively
- Recognize priorities that are important from a TEK perspective
- Build and strengthen NPLCC partner relationships

III. METHODS USED TO DEVELOP THE S-TEK STRATEGY

For this Strategy, the S-TEK Subcommittee reached agreement on general Guiding Principles, determined Priority Topics, and developed examples of the kinds of actions that might be taken. Figure 2 illustrates the process the Subcommittee followed, adopting concepts from structured decision making and decision analysis to ensure that the Strategy addresses decision- and management-relevant information needs, and incorporating ecological modeling elements to ensure inclusion of climate change impacts and uncertainties at the landscape scale.

A large universe of management-relevant climate change impacts and challenges was recognized, ranging from topic-specific information needs to generalized needs for certain types of analyses and tools. Concurrently with developing potential topics, the S-TEK specified the objectives for this Strategy and defined criteria for setting priorities among this "long list" of potential needs. The long list was then formally organized into topical areas and screened to identify a high priority "short list" of topics, each of which was then evaluated based on the identified criteria. The final set of Priority Topics combined the evaluation results with portfolio balancing considerations. Implementation of the Strategy and future revisions of the Strategy (steps 5 and 6) remain as future tasks for the S-TEK Subcommittee.

The S-TEK Subcommittee implemented this process over a six month period with two face-to-face meetings and nine phone and web-based meetings. The steps are described further below, and additional information on the methods is included in the detailed *Technical Supplement to the NPLCC Strategy for Science and TEK (*http://www.fws.gov/pacific/Climatechange/nplcc/*).*

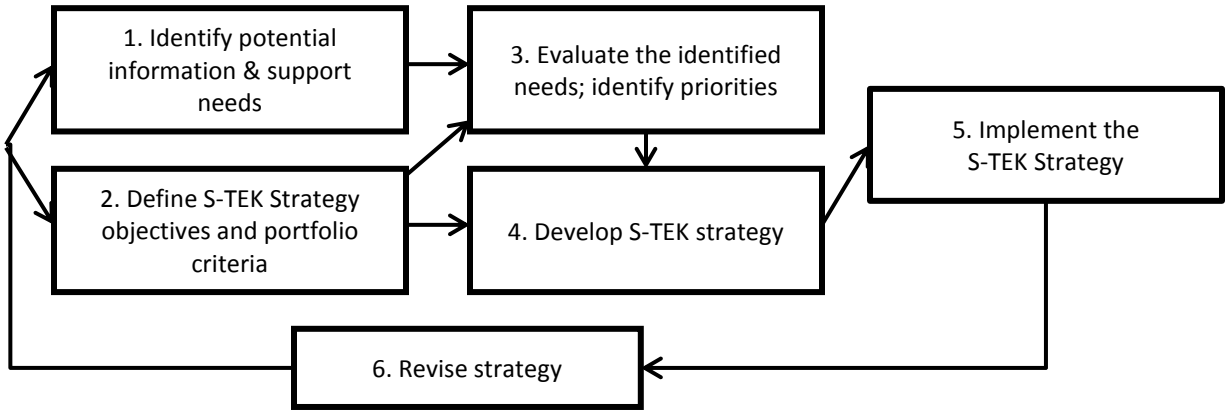


Figure 2. Steps in S-TEK Strategy Development.

Identification and Organization of Potential Information and Support Needs

To identify a comprehensive set of possible climate-related information and support needs of NPLCC stakeholders, the S-TEK Subcommittee pursued four approaches simultaneously. Figure 3 shows the various efforts that contributed to the development of this "long list" of potential needs, and each is described briefly below:

- ***Steering Committee Framing:*** A Framing Workshop in October, 2011 identified a set of conservation and sustainable resource management decisions that the NPLCC aims to support and a variety of outcomes of interest to natural resource managers (http://www.fws.gov/pacific/Climatechange/nplcc/framework.html). This overall framing provided the necessary structure for identification of decision-relevant information and support needs for the S-TEK Strategy. Steering Committee members also identified a few of the key uncertainties about climate change effects as they related to resource management decisions, and those were carried forward into the "long list" of potential information needs.

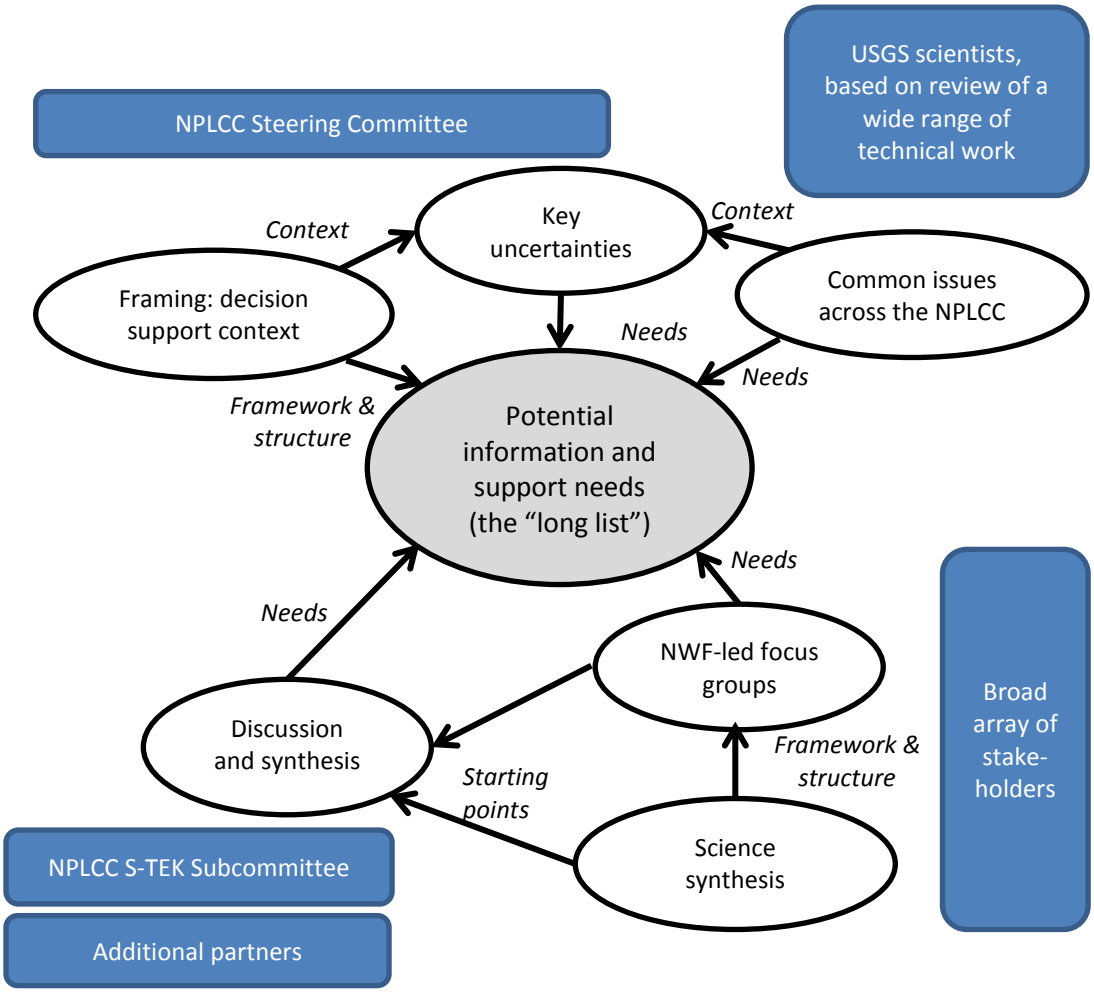
- ***USGS Scientific Support to the Steering Committee:*** The U.S Geological Survey (USGS) developed a set of conceptual models of climate change effects in ecologically defined subregions of the NPLCC, and identified a set of issues common across the entire NPLCC. Findings reported to the Steering Committee both provided an ecological context and identified some specific areas where additional information and support might be broadly useful (http://pubs.usgs.gov/of/2012/1211/).

- ***National Wildlife Federation Support:*** Funded by the US Fish and Wildlife Service and NPLCC, work led by the National Wildlife Federation (NWF) provided the most robust and important input concerning potential information and support needs. Two major activities informed the identification of needs:
  - Science synthesis reports were developed based on more than 400 relevant scientific papers and more than 100 personal interviews distilled information about climate change effects and adaptation approaches for two principle ecosystem types: a) freshwater aquatic and riparian ecosystems; and b) marine and coastal ecosystems within the NPLCC. Draft findings provided in August, 2011 summarized historical baselines, observed trends, future projections and information gaps (http://www.fws.gov/pacific/Climatechange/nplcc/products.html). Similar work is currently underway for the terrestrial ecosystem.

  - Surveys were undertaken and focus groups convened, structured to identify challenges, opportunities, and potential strategic science and TEK needs and priorities. This process involved a total of about 200 participants in a web-based survey to identify initial challenges and information gaps, thirteen web-based focus groups to elaborate on those challenges and gaps, and three full-day face-to-face workshops where participants identified higher priority topics and described the decision-relevance, spatial scale, temporal scale, timeline, and sense of urgency of addressing those gaps. Participants were affiliated with U.S and Canadian Federal government agencies, Tribes and First Nations, non-governmental organizations, academia, and State and Provincial agencies.

- ***S-TEK Discussions and Ecosystem Work Groups:*** The S-TEK Subcommittee reviewed results of the above activities and engaged in focused discussion and identification of potential needs through three ecosystem work groups corresponding to the three ecosystem types mentioned above.

Subcommittee members identified connections between key natural resources, the ecological processes affecting those resources, and relevant management decisions and knowledge gaps.



Note: Each white oval refers to a distinct effort that either directly identified potential information and support needs, or defined the context and structure for the identification of those needs. Blue boxes indicate the groups involved in each effort.

Figure 3. Potential Information and Support Needs: Approaches and Participants.

Organization of Identified Needs. A large number and variety of potential information and support needs emerged from these activities. Some needs were topical (e.g. effects of a warming climate on temperate rainforests) while others encompassed both approaches and topics (e.g. development and application of decision support tools,) defined as a potential need for many different topics. Potential needs that were not topic-specific led to the definition of four key Guiding Principles described in Section IV. These Guiding Principles are not tied to any one specific topic, but are potentially relevant to multiple topics. Topical needs were formally organized, evaluated and ranked via with methods described below.

Ranking Criteria and Portfolio-balancing Considerations

Objectives that describe how the Strategy could best meet or support the NPLCC Goals and Mission were identified early in strategy development. These objectives led directly to the identification of four specific criteria (see sidebar) to be used to evaluate and rank the topic-related potential information and support needs: to create a "short list" of topics from the "long list."

The S-TEK Subcommittee also recognized the need for portfolio balance in the Strategy. Like a portfolio of investments, the best mix of activities consists not merely of the top ranked options on a list; a diverse or balanced portfolio is typically preferred. The Subcommittee identified several types of diversity or balance consistent with the NPLCC Goals that will lead to a more broadly useful set of activities both within the Strategy and in annual implementation plans. These portfolio-balancing factors (see sidebar) were used in combination with the evaluation criteria to select the final set of Priority Topics.

Criteria and balancing factors for selecting Priority Topics

Four primary criteria determine the relative "ranking" of a topic area:

- Value of information for decision-making
- Breadth of need across NPLCC stakeholders
- Importance of LCC-level participation.
  - How large is the information or support gap?
  - How critical the LCC is to filling that gap?
- Timing of need

In addition to the ranking of topic areas, the S-TEK subcommittee considered several balancing factors to select the portfolio of topics that best meets the overall objectives of the Strategy and the goals of the NPLCC:

- Relevance to three ecosystem types: Marine/coastal, freshwater, and terrestrial
- Relevance of the topic to the States, Province, Tribes/First Nations that are part of the NPLCC
- Relevance of the topic to outcomes of interest identified by the Steering Committee
- Geographic scale of the issue

Evaluation and Ranking of Topics

To organize, screen, and rank topical information and support needs, the S-TEK Subcommittee went through two evaluation exercises. First, potential needs were organized and screened through development of an "Impact Matrix" to relate the effects of defined climate-related drivers on specific valued natural and cultural resources. Second, to rank the most important needs emerging from this process, a formal ranking tool was developed and applied to yield the highest Priority Topics for the Strategy. Figure 4 illustrates this sequence of activities.

Impact Matrix Screening: The matrix included 16 climate-related drivers and 27 valued resources. The matrix cells represented driver/resource pairs, such that a specific driver (e.g. sea level rise) could impact one or more valued resources (e.g. shellfish, coastal wetlands), and a specific resource could be impacted by multiple drivers.

S-TEK Subcommittee members independently scored each cell with an allotted 100 total points each, distributing points among cells to reflect: (a) the degree to which information or support related to a topic was needed to support natural resource management decisions in the LCC; (b) the magnitude or importance of the effect of the driver on the resource; (c) the level of uncertainty about those impacts; and (d) the necessity and ability of resource management agencies to mitigate, adapt, or respond to the anticipated climate driven changes.

The top-scoring 22 driver-resource pairs represented in the matrix were selected as a short list of topics for ranking and further discussion and development. Those topics combined received more than 30% of the total number of points allocated, and each individually had received at least 1% of the total number of points allocated.

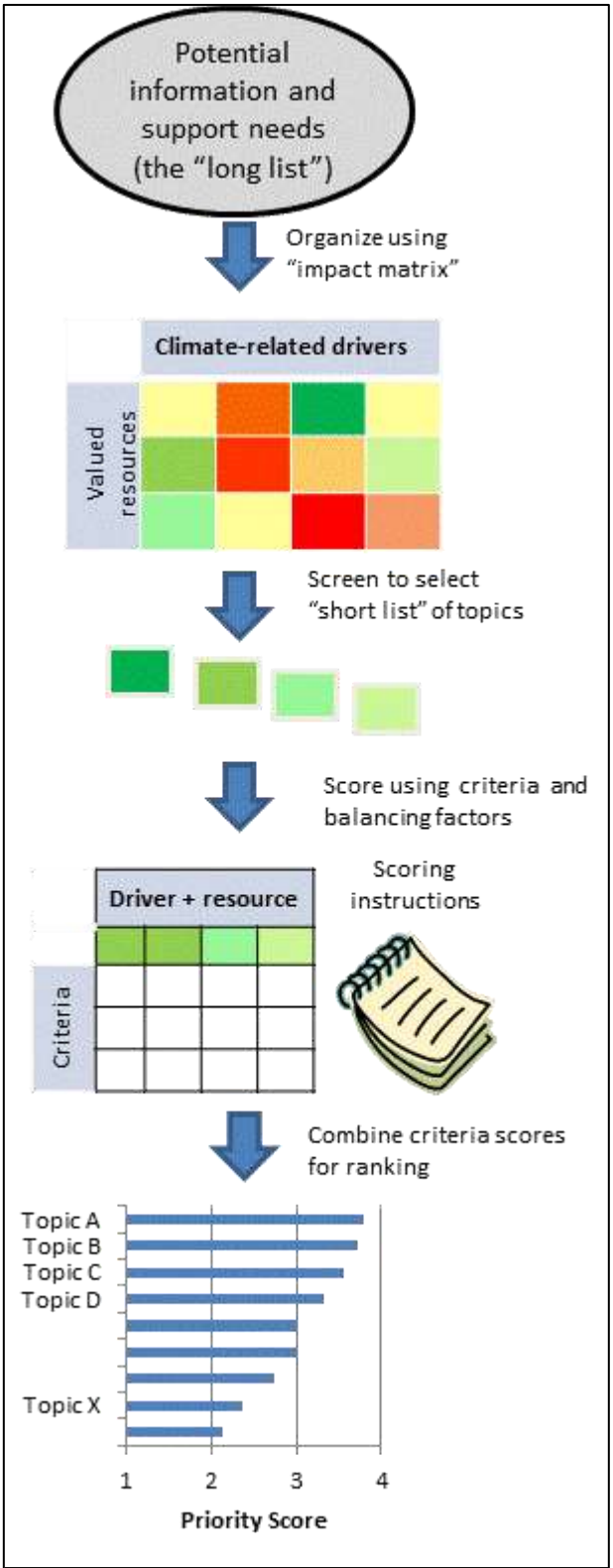


Figure 4. Organizing, Screening, and Ranking Potential Topics.

Ranking of Topics: Ranking of the 22 "short list" topics resulting from the screening process was undertaken using a second evaluation tool. The ranking tool included explicit, well-defined scales for each of the evaluation criteria and portfolio-balancing factors. For this evaluation, scoring was undertaken only by individuals with technical expertise in and/or management responsibilities related to the topic. This reduced the evaluation burden for the subcommittee members to a manageable level, and reduced the opportunity for motivational bias to affect the relative scores across different categories of topics. This approach, however, meant that each topic was evaluated by a relative small (but knowledgeable) set of 5-9 individuals.

Final Selection of Priority Topics

The rank-ordered short list of 22 topics was reviewed by the Subcommittee. They considered the ranking results, detailed definitions of topics (driver-resource pairs), portfolio balance (with particular emphasis on addressing topics within each of the three ecosystem types), and the emerging priorities from the NWF focus-group work described above. During this discussion, several closely-related topics were combined and others were slightly restructured to yield a final list of five Priority Topics described in Section V. These five topics included at least some aspects of 15 of the 22 topics evaluated in detail.

IV. GUIDING PRINCIPLES

Four principles were adopted to guide all aspects of planning, based on S-TEK deliberation during the screening and ranking exercises and results from the NWF focus groups. Principles were not tied to specific topics, rather they encompass a variety of approaches that can be used to address an identified information or support gap. They will have a critical role in the identification of specific activities during the annual planning cycles. The Guiding Principles highlighted in the sidebar and described below are considered equally important:

Principle A*:* *Focus on helping managers understand the availability and effectiveness of climate change adaptation and mitigation response actions.* To help inform conservation and sustainable resource management decisions under a changing climate, a focus on adaptation and mitigation response actions, including consideration of resiliency, was identified as being a more pressing need than improved understanding of the impacts of climate change. It was recognized, however, that for some topics new scientific information may be needed, and this will be a secondary focus for the NPLCC.

Principle B: *Facilitate coordination, collaboration, and capacity building, developing or assisting with tools to assist decision-makers*. The NPLCC will focus its efforts on types of information and support where partner entities have (historically) focused less effort. The NPLCC is uniquely situated to add value by facilitating coordination, collaboration and capacity building within and among Partner entities, and developing or assisting with tools to help entities use science and information effectively and appropriately in decision-making. Generating new data and scientific findings is a secondary activity for

the NPLCC. The NPLCC will look to the Climate Science Centers and others in the scientific community to take a leadership role in helping fill gaps in scientific understanding.

Principle C: *Identify and promote opportunities to use TEK, where desired by Tribes and First Nations, to support partner and stakeholder decisions.* TEK is an important contribution to understanding both the effects of climate change and the availability and effectiveness of adaptation and mitigation actions. Shared TEK can provide information and inform NPLCC partner decision-making, and should be considered by NPLCC partner entities. The NPLCC recognizes the sensitive and proprietary nature of TEK and the need for any TEK use to be approved by Tribes and First Nations, as well as the need to follow identified protocols that recognize the full protection of rights. TEK is confidential and culturally sensitive information for many Tribal communities. The sharing of this information may be limited or restricted in order to respect those considerations.

Principle D: *Promote and facilitate consideration of the connections and interactions between ecosystems.* The NPLCC contains intricately connected ecosystems that include marine, terrestrial, and freshwater environments. Many valued natural and cultural resources are dependent on and affected by several of these ecosystems simultaneously, and efforts to address impacts on those resources in only one ecosystem often fall short because they ignore ecological interconnections. Cross-ecosystem connections and physical and biological interactions will be recognized and addressed where appropriate and possible.

Guiding Principles

In annual implementation planning, and in the activities it supports, the NPLCC will:

- Focus on helping managers understand the availability and effectiveness of climate change adaptation and mitigation response actions
- Focus on facilitating coordination, collaboration, and capacity building, and on developing or assisting with tools to assist decision-makers
- Identify and promote opportunities to use TEK to inform partner and stakeholder decisions
- Promote and facilitate consideration of the connections and interactions between ecosystems

V. PRIORITY TOPICS

Organization, screening, and ranking of numerous potential topics yielded five Priority Topics agreed upon by the NPLCC S-TEK and Steering Committee. These are summarized below and listed in the sidebar.

Topic A: Effects of Hydrologic Regime Shifts on Rivers, Streams, and Riparian Corridors

The ecoregion is drained by numerous streams and rivers of all sizes fed by rainfall, snowmelt, groundwater, and (primarily in the north) glaciers. Fresh water, riparian and marine environments are closely interconnected in the region. They are influenced by diverse physical and biological processes associated with the seasonal timing, quantity, and quality (i.e. temperature, suspended solids, turbidity) of the water flowing in rivers and streams. Climate change influences hydrologic regimes by altering timing and quantity of precipitation (directly affecting runoff), type of precipitation (snow versus rain and precipitation stored as snowpack and ice) and temperature (affecting evapotranspiration and snow and glacier melt rates and timing). Seasonal flows in basins that currently have high snowmelt contributions are likely to become more rain-dominated in a warming climate, causing earlier, higher, possibly more frequent peak flows, and reduced summer flows.

Priority Topics

- Effects of hydrologic regime shifts on rivers, streams, and riparian corridors
- Effects of change in air temperature and precipitation on Forests
- Effects of changes in sea levels and storms on marine shorelines, the nearshore and estuaries
- Effects of the changes in the hydrologic regime on anadromous fish
- Invasive species, diseases, pests and their effects on biological communities

Altered hydrologic patterns would in turn affect a variety of ecological processes including nutrient cycling, phenology, quality of habitats, or success of critical biological events such as salmon spawning (see Topic D). Riparian corridors and associated wetlands, river deltas, estuaries and the marine nearshore are also directly and indirectly influenced by the same altered physical processes including nutrient dynamics and related ecosystem cascades. Warmer waters will alter aquatic communities due to the differing temperature tolerances of the species that currently reside there, for example, by creating new species associations.

Management Importance to LCC: Changes in hydrologic regimes are likely to affect food webs (including both primary and secondary productivity and higher level predator-prey relationships), aquatic species population dynamics, ecosystem processes, riparian and coastal vegetative communities, and system dynamics. Habitat availability and suitability for economically and culturally important species is likely to change and adaptation strategies will need to be developed to identify key areas to maintain harvestable or protected populations.

Assessing relative vulnerability and resiliency of river segments to climate change impacts, especially temperature, flow, bed scour, erosion, and elevated flood potential will be important to support habitat protection and restoration decisions. For example, some aggraded river systems have elevated flood potential, and extreme weather events can lead to severe and widespread damage to natural and

cultural resources and resource-related infrastructure. Understanding the availability and effectiveness of actions to increase system and species resiliency to flow regime changes may help support river management decisions and restoration prioritization and design, and may be particularly important for systems with unmanaged flows.

Other systems with highly managed flows will also present challenges. For example, many river systems in British Columbia, Washington, Oregon, and California have been altered to generate hydropower, provide water supplies, and manage floods under historical—not future—flow regimes. Modifications to flow management at dams, diversions, and levee systems in response to novel flow conditions will both directly and indirectly affect natural resources. The relationship between these management changes in these river systems and their impacts to natural and cultural resources will likely affect the need for and the effectiveness of habitat restoration and protection decisions. .

Topic B: Precipitation and Temperature Change and their effects on Forests

The dominant biome in the NPLCC is the coniferous temperate rainforest; sustained throughout its range by a maritime climate, including fog in southern locations and by more than 200 cm of rain annually in many northern locations. The commercial harvest of timber remains among the most important socio-economic drivers in the region, and recreational and ecologic values of these forests are also critically important.

Temperature and precipitation are primary drivers affecting the state of these forests. Habitat characteristics of the forest community as a whole are shaped by the climate niches of individual tree species, which are defined by factors such as elevation and snow depth at high elevations, glaciation (in the north) and slope aspect (particularly in the south). Each tree species distribution can be viewed as adaptation to particular dynamic climate factors. As changes to these factors accelerate due to climate trends, the mix of species at a given location or elevation is likely to change due to variation in dispersal ability of individual tree species and local extinctions.

Climate-driven changes in forest biomes are now emerging, including insect infestations triggered by warming and/or drought and changing vegetation patterns which alter water storage in watersheds (see additional implications in Topic E). Projected temperature and precipitation changes are not uniform throughout the NPLCC, and their effects are uncertain. Increased drought is a significant factor influencing fire frequency and other stressors. Within forests, soil biogeochemistry and microbiology, forest dependent fauna, understory plant diversity, and a variety of other forest attributes also will be affected by climate change. Many of these changes are likely to occur through complex, indirect secondary mechanisms forced by precipitation and temperature—such as fire, insects, and disease – with large scale effects at basin-wide or geographic scales.

Management Importance to LCC: The forest that characterizes this biome is significant on a global scale; one third of the world's old growth temperate rainforest is found in just the Tongass National Forest. Understanding current and expected plant and wildlife sensitivities to climate change and

management response actions is necessary for the development and implementation of successful adaptation strategies and actions. Migrations northward or to higher elevations—of species and/or entire communities—are likely to affect resource management needs within the NPLCC. An increasing number of observations document the effects of warming on ecological timing of interspecies processes such as pollination and reproduction; these phenological changes within communities typically lower the fitness of co-dependent species.

Community level attributes will also be affected, including trophic webs, keystone relationships, and the distribution of co-evolved plant species that defines vegetative cover that supports habitat and connectivity benefitting other species. Protection, restoration, and management activities for sensitive and rare species, managing for biodiversity, and addressing habitat fragmentation and wildlife migration corridors will benefit from consideration of climate-induced changes in forest ecosystems. Examples of the types of forest management actions that could be modified with improved understanding of the effects of climate change include: forest thinning; prescribed fire severity to reduce competition; and planting species of genotypes that are bettered adapted to warmer conditions following major disturbances resulting from more stressful climatic conditions.

Topic C: Effects of Sea Level Changes and Storms on Marine Shorelines, the Nearshore, and Estuaries

Land and sea are intimately connected in this ecoregion. Much of the 38,200 miles (~ 61,500 km) of coastline in the NPLCC region is sinuous and studded with islands. Sea level rise is accelerating globally due to land-based ice melting and thermal expansion of sea water in a warming climate—processes that are projected to result in 1-2 m average sea level rise this century. However, localized influences are also very important. For example, the coastline at Gustavus, Alaska, a region known for recently diminished glacial ice, has increased in elevation approximately 6 m in 2 centuries due to isostatic rebound. Local vertical land movements are also important influences on sea level changes in the NPLCC. Plate tectonics drives coastal uplift along several west coast faults within the ecoregion, raising the shoreline at a rate nearly equivalent to global mean sea level rise. Finally, coastal impacts of sea level rise are most severe during extreme storm events; therefore storm frequency and severity are inherently important.

Management Importance to LCC: Much of the societal concern for sea level rise relates to human infrastructure, particularly in urban areas managed by local governments. The NPLCC is focused on impacts to natural and cultural resources region-wide, and on impacts to resource-related infrastructure (for example in National Forests, on Crown Lands, or related to Tribes or First Nations). Many coastal natural and cultural resources and resource related infrastructure are likely to be affected by sea level changes and coastal storms including coastal wetlands (which because of the high topographic relief throughout most of the LCC, may not have space to move inland); nearshore habitats such as seagrass beds (important to juvenile salmon and many other species); shellfish beds (an important First Food and economic resource); mudflats (important to migratory birds), and beaches (specific substrates and elevations are needed as by some forage fish species as spawning habitats). The effects of sea level rise and coastal storms need to be considered in adaptation planning to address the needs of marine fish

and wildlife. Sea level rise and storms also needs to be specifically addressed in designing restoration and mitigation sites, as well as the selection of habitats for protection.

Topic D: Hydrologic Regime Influences on Anadromous Fish

Because of their iconic ecological, cultural and economic status throughout the NPLCC, anadromous fish provide perhaps the best example of a highly valued natural resource likely to be influenced by climate-driven changes in hydrologic regime. Anadromous species (including the "Pacific salmon," steelhead, coastal cutthroat, the bull trout/Arctic char/Dolly Varden complex, and lampreys) have served the nutritional and ceremonial needs of indigenous peoples for millennia. The commercial harvest of salmon and timber (see Topic B) remain among the most important socio-economic drivers in the NPLCC region and they support human recreational pursuits and associated economies throughout the region. Salmon also have high ecological value; for example marine-derived nutrients from salmon carcasses are important in supporting riparian plant communities and terrestrial carnivores and scavengers in addition to future generations of salmon.

While the wellbeing of anadromous fish is an LCC-wide conservation issue, the health of populations and potential impacts from climate change vary regionally and locally. Rivers and their tributaries differ in flow contributions from snowmelt, rainfall, and groundwater—each with different hydrological implications for the fish under a changing climate. For example, where groundwater contribution to stream flow is high, changes to the seasonal pattern or type of precipitation have less effect on summer flows than in places where rainfall runoff is the main source of flow. And finally, successful spawning and rearing in rivers is dependent on the sustainable transport and deposition of the coarse sediment comprising the streambed, bed scour dynamics that allow for successful redds, and the input and persistence of large woody debris and other materials to form complex habitat. All of these habitat-maintaining or creating processes for anadromous fish (and other aquatic species that may be important to them) are affected by climate change.

Management Importance to LCC: Managing and protecting anadromous fish populations will require incorporating climate change into planning, decisions and actions. For example, some genetically distinct populations of anadromous fish in Washington, Oregon, and California are listed under the U.S. Endangered Species Act or are at risk (e.g., certain salmon and steelhead in the Columbia River Basin and Puget Sound). These populations—already at risk—will be subject to additional climate related stressors that must be considered in recovery planning. Because salmon life stages depend upon the interconnected ecosystems extending from mountain headwaters to the open Pacific Ocean, these species and their habitats integrate these systems and thereby serve as a general indicator of ecological conditions.

As climate change influences hydrologic regimes, anadromous fish throughout the geographic range of the NPLCC will be affected. Multiple climate-related issues will need to be considered in making habitat protection and species management decisions. These issues potentially include: increased water temperature and the progressive loss of "temperature refugia" (especially for cold water species in the

southern portions of their range); alteration of physical characteristics of spawning and rearing habitats; and changes to off-channel rearing habitats. Management decisions will also be influenced by understanding the effects of increased frequency of scouring of redds due to high flow events; migration barriers created by reduced summer flows or high water temperature; climate-related changes in hydropower management; alteration of food chains in both upstream and estuarine environments; increased frequency of disease outbreaks or virulence and triggering of novel diseases associated with increased stress; and invasive species influences on populations.

Topic E: Invasive Species, Diseases, Pests and their Effects on Biological Communities

Species invasions, changes in populations and distributions of native nuisance species previously at low levels, and changes in prevalence and distribution of diseases and pests can have significant population-limiting influences on biological communities and on the services provided by ecosystems. Some 20 to 40 percent of extinctions worldwide (depending on taxa) are thought to result from invasive species.

The possible mechanisms driving these impacts are numerous. As climate-driven stressors affect native species, which may be more narrowly co-evolved with their environment than invasive species, invaders, especially parasites and pathogens, may have a competitive advantage. Plant species distribution changes, such as the northward migration of some species and appearance of novel species in new areas, are expected to change vegetative communities in ways that affect habitat suitability and occupancy for fish and wildlife, with some species being influenced more than others. Warming may trigger better conditions for invasive pathogens, parasites, or species that harm or compete with native species in aquatic and terrestrial communities. Aquatic and marine invasive species are likely to respond to water temperature and hydrologic changes and can affect food webs and biodiversity.

Management Importance to NPLCC: With the added influence of climate change, invasion pathways, rates, and impacts are likely to emerge in unforeseen ways that will call for novel management or adaptation actions for natural and cultural resources. Identifying early invasions, diseases and pest expansions or outbreaks and anticipating those likely in the future will help managers develop management strategies to address these new biological communities.

Understanding the effectiveness of different prevention and control strategies under future conditions will lead to more effective management actions. Most state and local entities are only just beginning to consider systematic responses to invasive species, diseases and pests. Climate-driven disturbance to processes such as fire regimes or life-cycle advantages which benefit invaders (as in the case of warming and its effect on pine bark beetles in British Columbia) will require much different strategies and techniques for implementing forest and fish and wildlife management. As climate change further influences the multiple interacting stressors that shape invasions, successful adaptation will require substantial new kinds of information specific to NPLCC landscapes.

VI. IMPLEMENTING AND UPDATING THE STRATEGY

This S-TEK Strategy will be the framework for developing the NPLCC's annual implementation plans for the next four years. This Strategy will also be used to communicate with the three Climate Science Centers that provide support to the NPLCC. The NPLCC will work closely with the Alaska, Northwest and Southwest Climate Science Centers so priorities identified in this Strategy will also be reflected in their annual implementation plans. LCCs are a primary customer of the Climate Science Centers which are committed to helping fulfill LCC science needs.

This Strategy will be shared within partner organizations so they can implement identified or complementary actions that are consistent with their own individual goals and responsibilities. Many of the NPLCC partner organizations are engaged in climate related actions to individually address challenges they face. Regional and national opportunities exist for NPLCC partners to work together to address priority topics, principles and actions. This Strategy, in conjunction with Annual Implementation and other NPLCC outreach can be used to help integrate efforts where practical and to avoid duplication. Additionally this Strategy will be shared with adjacent LCCs to help with a seamless and transparent delivery of science and support planning.

Annual Work Plans

Implementation of this strategy will occur through an annual planning process. As was the case with this Strategy, each annual implementation plan will be developed by the S-TEK Subcommittee, subject to subsequent review and approval by the NPLCC Steering Committee. The annual work plans will describe actions that fall within the framework of this Strategy; that is, specific activities that are consistent with both the Guiding Principles and Priority Topics. A structured process for defining these annual implementation plans is still being developed and will include consideration of the following steps:

- Identify available resources to support work, both NPLCC-directed resources and any resources from partner entities that they choose to focus on NPLCC priorities
- With reference to the Priority Topics, Guiding Principles, and previous and ongoing work, identify potential actions for the annual effort. The potential actions could include, for example:
    - Develop, describe, and/or evaluate alternative adaptation responses to climate-induced changes to support resource conservation.
    - Evaluate ways to enhance the resiliency of valued resources to climate-related stressors
    - Develop tools to assist managers and decision-makers in response to particular expressed needs.
    - Synthesize existing information for meaningful specific applications agreed upon through partner collaboration.
    - Collect new scientific data and develop synoptic findings to fill recognized gaps in information to support resource management and conservation.

- Collect and synthesize traditional ecological knowledge through engagement with Tribes and First Nations
- Strengthen the NPLCC collaboration through joint information gathering, sharing, and other forms of capacity building.

- Select a set of potential actions to pursue. Figure 5 shows an example of a planning tool that is likely to be used: it lists the Priority Topics as rows, and identifies a variety of different potential actions in the columns. Details on remain to be worked out, but several options for the use of this table are possible:
  - Could select a single row, and focus on a single topic for one year through multiple types of actions
  - Could select a column, and pursue one type of action for multiple topics
  - Could select individual cells, and focus on the most useful or beneficial action for multiple topics

- Highlight areas of focus that are time critical (for example, ongoing efforts with leveraging potential, an emerging science need, etc.)
- For each area of focus for the annual plan, determine how best to pursue and fund work on the topic. Identify efforts currently being undertaken for selected topics to avoid redundancy and ensure that the NPLCC's efforts will be complementary to or will supplement those efforts, but not be duplicative
- Coordinate efforts with the Climate Science Centers, adjacent LCCs and individual LCC partners

	Potential Actions							
	Information on adaptation and response actions	Development or assistance with tools to help entities use	Synthesis existing information	Generation new science, information, or data	Collection and synthesis of TEK	Facilitation of information sharing, collaboration, capacity building	Information related to resiliency	Etc (to be determined)
Topic A								
Topic B								
Topic C								
Topic D								
Topic E								

Figure 5: Example of a Topic / Activity matrix that will be used during Annual Work Plan development.

Revisions and Updates

The S-TEK Subcommittee intends to update this Strategy periodically according to the NPLCC planning schedule (e.g. next revised for 2017), but also recognized that there could be reasons to revisit or revise the Strategy prior to 2016. For example, several NPLCC-funded projects are underway or are planned for 2013 that could suggest new priorities or modifications of those currently included in the Strategy. Some of these efforts will broaden participation in the identification of topics and principles, and others will provide additional detail and structure to topics already identified.

Tribes and First Nations were under-represented on the S-TEK Subcommittee. Two activities are underway that may lead to the identification of additional Priority Topics:

- The NPLCC Tribal and First Nations Committee, still in formation, will be asked to review and comment on this Strategy.
- The NPLCC funded seven projects in FY2012 related to the how and where TEK can be incorporated into the work of the NPLCC. As those projects produce results, they may highlight new topics where information and support is needed, and/or may identify areas or protocols where TEK can provide particularly useful information for decision-makers.

Additional activities are underway or planned that may affect the definition of a topic, or S-TEK understanding of the importance of NPLCC activities in developing information and support related to that topic. Those include:

- USGS-led development of conceptual models describing predicted climate change impacts to resources having management priority; management responses to predicted changes; information needed to support potential management decisions; and relevant information gaps. Two of the models directly relate to the identified Priority Topics (hydrologic regimes/glaciers and forest cover). These models can be used by the S-TEK to support development of the annual work plans or to refine the topics.
- Two NPLCC-supported workshops, led by NWF, will be held in winter 2013 for managers and scientists to come together and discuss management decisions, information gaps and support needed related to one or two of the Priority Topics.